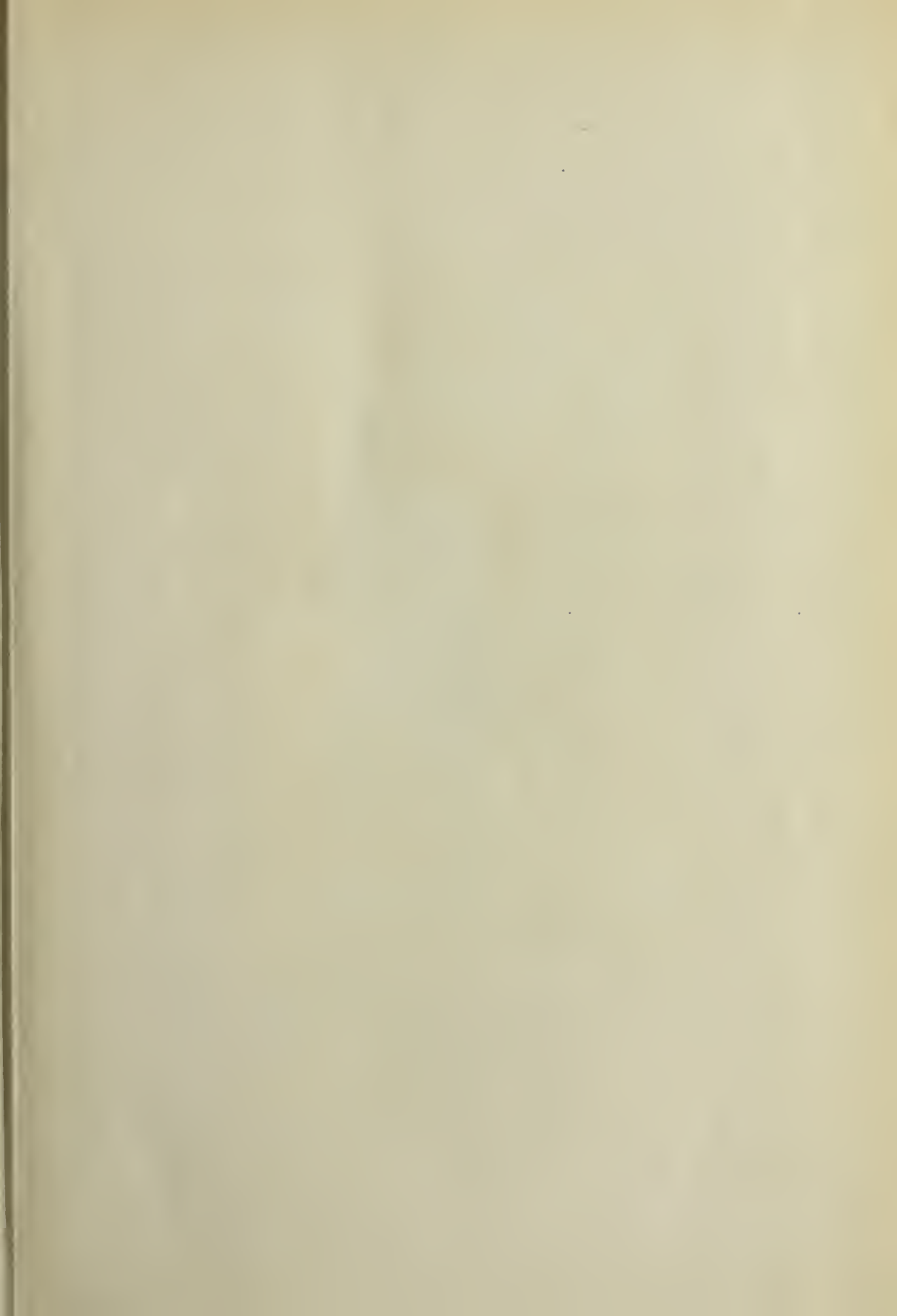


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BLUEPRINT FOR MALARIA ERADICATION IN THE UNITED STATES

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The eradication of malaria as a significant public health problem in the United States has been proposed as a cooperative enterprise of the several State Departments of Health concerned and the U. S. Public Health Service. Through this joint effort, an attempt is being made to reduce the incidence of the World's No. 1 communicable disease to virtual extinction in a large, defined area. It is our purpose in this discussion to review briefly the pattern of development and operation of this program. As many will recall, the original proposal for this all-out attack on malaria was the idea of Dr. Louis L. Williams, Jr., whose plan was presented in a paper by Dr. J. W. Mountin at the 1943 meetings of this Society.

Many of the elements, both apparent and obscure, which tend to render malaria in this country vulnerable to such an attack with reasonable hope of success, were discussed in Dr. Mountin's paper and have been analyzed further in other presentations during these meetings. It is apparent that both specific and non-specific beneficial agents affecting the transmission and maintenance of the disease have produced a favorable set of circumstances for the mobilization of a strong malaria control effort. The health agencies of the affected areas, therefore, are collectively "striking while the iron is hot."

In the selection of suitable procedures for operational activities three approaches to the goal were considered: (a) the elimination of malaria parasites in human residents of the areas; (b) the complete annihilation of the insect vectors of malaria; and (c) what may be termed "attritional eradication," effected by concurrent reduction of malaria parasites and vectors to the point where general malaria transmission cannot occur.

There are certain inherent weaknesses in the first two methods. The lack of suitable means for mass destruction of the parasites in man by medication and the practical difficulties for such therapeutic administration to the general public in affected areas, eliminate the first. The technical and operational difficulties connected with any attempt at country-wide eradication of native anopheline species, as well as the prohibitive cost of a program, eliminate the second. The last approach, therefore, was selected as the only one practicable for achieving malaria eradication in the United States. It is believed to be the most economical and efficient plan since it incorporates the advantages of the other alternatives without their difficulties.

Federal, state and local health agencies generally have accepted the challenge and

have embarked enthusiastically on the five-year program of major effort. The administrative pattern adopted has provided for establishment of broad general policies within the mandates of Congress and under terms of the federal appropriations with the actual administration of authority and management of operations vested in the state departments of health. Technological information is developed and tested through laboratory and field investigations, and disseminated throughout the program by means of printed and audio-visual materials and personal contacts. The uniform use of recent developments and recommended practices is promoted by centralized training courses for key personnel. These are followed by decentralized training of personnel in the lower echelons. This concept provides for a general and intelligent application of fundamental technical principles and at the same time allows sound variations in procedures where desirable due to local circumstances. The plan of organization permits the establishment and application of national policies to the program as a whole while basing the integral function of administration of the work in state and local departments of health, thus encouraging permanent and active malaria control organizations at these levels.

In the control program principal reliance is being placed, first, on killing of adult anophelines in human habitations using residual insecticides, and second, on improved diagnosis and treatment of malaria cases. The organized field activity—DDT residual spray applications in houses and other human habitations—is conducted by the various State-CDC Activities organizations in the areas of traditional greatest malaria endemicity. The usual unit of operation is the county and projects are mostly county-wide, as is necessary because of substantial local financial participation. The DDT treatments consist of applying emulsion to all interior wall surfaces and porches of houses and such other structures as privies, to obtain a coating of approximately 200 mg. of DDT per square foot. In most areas two treatments per season have been provided, although there is now a trend towards a single spray per season. In marginal areas of malariousness, "spot-spraying" is followed in which only the houses of known malaria cases and nearby residences are sprayed. Where actual cases of malaria are known to exist, treatment of entire premises is practiced. Complete spraying of premises on a routine basis is desirable, of course, for more comprehensive anopheline kill, but it appears that a high degree of malaria control is obtained with routine house and privy spraying only. This practice conforms to the expressed purpose of utilizing available federal funds to tip the scales in favor of non-transmission. Larger local financial participation can be used to extend coverage over entire premises.

The spray is applied by small crews of two or three men operating from a light truck on which DDT concentrate or mixed emulsion, sprayers, and air tanks or compressors are transported. In areas such as suburban communities, where premises are close together, power sprayers often are used. Prior to actual spraying, a contact man solicits assistance from householders in moving furniture to the center of each room and in protecting valuable possessions and food. The pre-season trained crews follow a definite pattern in spraying; emulsion strengths are adjusted and spray nozzles calibrated in advance in order that the proper amount of material will be

applied. Particular attention is given to safety precautions and to giving out authentic information to householders concerning the properties and limitations of DDT.

Direct entomological evaluation is obtained by afternoon inspections of random samples of sprayed premises at varying periods subsequent to spray treatment. Experience indicates that *Anopheles* mosquitoes are eliminated from practically all treated houses if the DDT has been applied properly.

The increased use by householders of both space and residual type insecticides is being encouraged for the genuine beneficial effect which this destruction of anophelines has in the program. The mass awareness of, and use of insecticides by the public in their homes, strikes a mighty blow at the specific insect vectors of disease.

Improved knowledge of current malaria prevalence is vital to both intelligent direction of the insecticidal program, and a concentrated attack on the detection and treatment of actual cases. To obtain this knowledge, the strengthening of epidemiological field services is being effected by medical and nurse officers made available to epidemiologists in states from which most of the malaria is being reported. The mission of these officers is to develop better diagnosis and reporting by practicing physicians, and to promote the use of the best available antimalarials. A follow-up of reported cases serves to emphasize accuracy in diagnosis and permits direct exposition of modern methods of treatment. Public health nurses are furnished to supplement available medical talent in malaria epidemiology. The nurses will also serve as stimuli to the general public health nursing program in encouraging a larger proportion of existing malaria cases to seek medical attention. It is expected that these field activities will serve to delineate areas of probable malaria transmission, which then can be subjected to concentrated entomological study and immediate operational nullification, if affirmative evidence of transmission is obtained. Procedures are thus established for a logical progression to point control efforts on the country's foci of residual infection. This is of obvious importance in the eradication effort.

In a few selected areas special studies are to be undertaken in order to determine intimately the epidemiology of malaria, particularly with respect to the maintenance of the disease in human populations. These "listening posts" will be located in areas of previous hyperendemicity where transmission factors can be analyzed and where, presumably, malaria will be most likely to return. In addition to a thorough study of the human cases, an ecological appraisal of the vector species will be undertaken to determine what circumstances tend to permit transmission of the disease, and also those which have been associated with malaria recession. When elucidated, these factors may provide additional means for breaking the links in the chain of malaria transmission.

We are now at the end of the first year of the planned five-year program. Control operations are underway in approximately 80 percent of the 400 most malarious counties of the country, that is counties having death rates of five or more per 100,000 during the period 1938-1942. Present plans call for the early extension of operations to the remainder of these counties and to isolated malaria foci in marginal territory as these can be delineated. Sufficient epidemiologic and entomologic data on the results

being obtained should be available at about the midpoint in the program to allow a thorough evaluation of progress and to determine whether any revisions in general procedures or selection of project areas is necessary.

Although it is believed that prospects for the success of this five-year eradication effort are very bright, it is not believed that its success will end the need for malaria prevention work in this country. Programs in many areas will need to be continued on a "maintenance basis" and constant surveillance will be necessary to detect any localized recrudescence of malaria in order that immediate steps may be taken to prevent spread. Each state department of health in the area concerned should continue to support a minimal program which would be sufficient to detect and control outbreaks. Highly mobile types of staff and equipment would be essential. The greater sensitivity to malaria among people of this country as they gradually become unaccustomed to its ravages will assist this work in the intelligence phases, as well as in elicitation of public support. Because the problem of reintroduction of the disease must be considered, it is encouraging to note the significant plans for strengthening malaria control in Mexico through initiation of a large DDT residual spray program. Technical personnel for this work are now being mobilized. Many other countries are also devoting strenuous efforts along similar lines. Of ports-of-entry, the principal sources of concern would be in the southeast, since malaria introduced in other areas will not likely be transmitted. Controlling transmission in the traditional malaria belt would be the task of the mobile units. We trust it is not too much to hope that in the years to come, malaria may be included in the same category as yellow fever and dengue—diseases which are prevented from becoming problems in this country by surveillance and quarantine activities.

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STUDIES ON IMPORTED MALARIAS

10. AN EVALUATION OF THE FOREIGN MALARIAS INTRODUCED INTO THE UNITED STATES BY RETURNING TROOPS¹

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Early during World War II, it became obvious that military personnel would bring back malaria infections acquired in foreign countries. Therefore, it was necessary to learn as much as possible about these foreign malarias and particularly how they would adapt themselves to conditions here. To determine this and to gather other information, the "Imported Malaria Studies" program was established with the cooperation of the Army, Navy, and U. S. Public Health Service.

Various phases of the problem have been reported in the first nine papers of this series (Young, *et al.* 1945, 1946; Moore, *et al.* 1945; Young, Stubbs and Ellis, 1946; Young, Ellis and Stubbs, 1946; Hardman, 1947; Eyles and Young, 1948; Eyles, Young and Burgess, 1948; and Young and Burgess, 1948). This report will summarize the findings of the entire program, correlate these with other information, and present conclusions based upon the data obtained.

METHODS

Studies on returned military personnel with foreign malaria were carried on cooperatively in 10 Army and Navy hospitals. There were eight coöperating state, Veterans', and private hospitals which used the foreign malarias for the treatment of neurosyphilis.

To test the susceptibility of mosquitoes, they were fed upon relapsing military personnel and upon neurosyphilitic patients with induced malarias. From these infections, parasitological studies were also made. Foreign malarias were found to be useful as therapeutic agents against neurosyphilis. By inducing these malarias in neurosyphilitic patients, certain strains were propagated which enabled more specific study of host-parasite relationship of the parasite in man and mosquito as well as making available a Pacific strain of malaria (Chesson *vivax*) for the large scale testing of new drugs. The details of the procedures used have been specified in the preceding papers of this series.

During the course of this program, of about 3½ years duration, mosquitoes were reared at the rate of one million per year. The majority of these were *Anopheles quadrimaculatus* and *A. maculipennis freeborni*, which are considered to be the principal vectors of malaria in the South and West, respectively. Other species tested in smaller numbers were *A. m. occidentalis*, *A. p. franciscanus*, and *A. penclipennis* from

¹ Contribution from the Imported Malaria Studies program of the Division of Tropical Diseases, National Institute of Health, and the Office of Malaria Control in War Areas, United States Public Health Service, P. O. Box 1344, Columbia, S. C.

the West Coast; and *A. punctipennis*, *A. p. pseudopunctipennis*, and *A. albimanus* from the South.

About 50,000 mosquitoes were fed upon military personnel with malaria and of these some 15,000 were dissected to determine infection rates. Additional mosquitoes were fed upon induced cases of foreign malaria.

Over 1,000 military personnel with relapsing malaria were observed to collect various types of data. Approximately another 1,000 patients, either neurosyphilitic patients or volunteers, have been given these foreign malarias.

The data from the above form the basis of the papers in this series.

OBSERVATIONS

Of the foreign malaria cases examined, none was *Plasmodium malariae* (quartan malaria).

There were eight cases of *P. falciparum* found. One of these from Guadalcanal infected 1 out of 28 *A. m. freeborni*; one *P. falciparum* from Africa infected 2 out of 10 *A. quadrimaculatus*. Six feedings on the other *P. falciparum* cases did not show any mosquitoes infected.

These data indicate only that foreign *P. falciparum* can infect our mosquitoes.

P. vivax was the important malaria studied because most of the infections in returning soldiers were of this species and it was the type responsible primarily for the relapses. The remaining part of this report will concern observations on this species.

THE PARASITE

Morphology. Careful observations were made to determine whether the foreign *vivax* parasites might show morphological differences which would be specifically characteristic and diagnostic. In addition to our own observations, Miss Aimee Wilcox, Associate Parasitologist of the National Institute of Health, examined smears from 71 different infections and to her we express our especial gratitude.

Even though the *vivax* infections originated from widely separated areas such as the South Pacific, Caribbean, and Mediterranean, no consistent morphological differences were observed.

On a few occasions, in two different *vivax* infections from New Guinea, forms were found which resembled *P. ovale*. The occurrence of these forms were transient, however, and it is believed that they were abnormal forms of *P. vivax*. These observations will be reported in detail elsewhere.

Strains. Lacking specific differential morphological characters, the indication of strain differences was secured by such criteria as immunity, characteristics of the primary infection, and relapse patterns.

Little heterologous immunity was shown between *vivax* infections from the South Pacific, China-Burma-India theatres and from the United States (Young, *et al.* 1947). In fact, one infection originating from New Guinea exhibited little immunity to another infection from the same area, suggesting multiplicity of strains in small areas.

Differences in the prepatent and incubation periods of malarias from the Pacific

and Mediterranean were demonstrated, the latter having the shorter periods (Young, *et al.* 1947).

Differences in the lengths of the asexual cycles were demonstrated in strains from the Mediterranean, American, and Pacific areas (Young, *et al.* 1947). In fact, strains from the same localities (New Guinea and Guadalcanal) in the Pacific area showed different periodicities.

Following treatment with certain drugs, a Pacific *vivax* (Chesson strain) isolated by us (Ehrman, *et al.* 1945) tends to relapse after a short latent period as contrasted to a long latent period as exhibited by an American strain (Coatney, *et al.* 1947, 1948a; Whorton, *et al.* 1947).

Because of the complexity of securing such data as the above, the differentiation of strains is slow. However, the results so far indicate that among the foreign infections brought into this country, there must be many different and distinct strains. As these are propagated in nature they are added to the various strains already indigenous.

THE PARASITE IN MAN

Susceptibility of Americans to foreign malarias. Approximately 1,000 white patients have been bitten by native anophelines infected with foreign malaria. Practically all of them were susceptible to these malarias as evidenced by a resulting infection, the failures being on the order of five per cent or less.

American Negroes are quite resistant to these foreign *vivax* malarias, from both the Pacific and Mediterranean areas. In one controlled study (Young, Ellis and Stubbs 1946), 31 per cent of the Negroes bitten by infected mosquitoes became infected as compared to 95 per cent of the white patients.

Thus, it appears that white natives of this country are almost universally susceptible to the foreign *vivax* malarias. The negroes are quite resistant, just as they appear to be to native *vivax* malarias.

The primary infections induced in neurosyphilitic patients. When these malarias were transmitted to patients by the bites of infected mosquitoes, usually 5 to 10, the prepatent and incubation periods (average 12.1 and 13.7 days respectively) in the Mediterranean strains were shorter than the same periods (average 13.1 and 14.4 days respectively) in the Pacific strains (Young, *et al.* 1947). A domestic strain, St. Elizabeth, showed longer prepatent and incubation periods (15.4 and 16.9 days respectively) than the foreign strains (unpublished data).

As indicated above, the parasites were usually present in the blood stream before the appearance of fevers but at the first fever of 100°F. the number of parasites per cmm. averaged only 21 in the Pacific strains and 45 in the Mediterranean strains in patients presumed to have a pristine susceptibility (Young, *et al.* 1947).

The parasites in the patients increased rapidly, attaining the peak parasitemias usually in the second week of the primary attack. These maximum parasitemias averaged about 14,000 per cmm., being higher in the Pacific than in the Mediterranean strains. The highest single parasitemias encountered were 44,200 per cmm. in a Pacific strain and 35,400 per cmm. in a Mediterranean strain.

The maximum temperatures (the highest temperature in a single patient) tended to occur several days earlier than the maximum parasitemias. These peak temperatures averaged 105.0°F. and were accompanied by parasitemias averaging 6,207 per cmm.

The average fever peaks for 934 paroxysms experienced by 79 patients was 104.5°F.

In the tertian type fevers, the average time between fever peaks (periodicity) was 44.4 hours for four Pacific strains and 45.1 hours for one Mediterranean strain. None exhibited a 48-hour periodicity.

Fevers were accompanied by chills 73.2 per cent of the time. The chills were less frequently present with the first five fevers than with the later fevers.

The type of fever at the onset of symptoms was usually quotidian or intermittent, only 8 per cent being tertian. The quotidian and intermittent fevers were readily converted to tertian occurrence by the use of sodium bismuth thioglycollate.

Usually the primary infection produced 10 or more paroxysms. Some patients had experienced as many as 22 paroxysms when the infection was interrupted by drugs.

Delayed primary attacks in military personnel. Many troops were infected with malaria under combat conditions but by use of suppressive drugs, a clinical attack after the usual incubation period was prevented. When the suppressive drug was discontinued, however, a clinical attack occurred which is termed "delayed primary attack". Two hundred such patients were studied, the majority of whom had acquired the infections in the Pacific and particularly in New Guinea (Eyles and Young, 1948).

The delayed primary attack occurred on the average 49.1 days after discontinuation of suppressive quinacrine (atabrine).

The parasite-fever threshold was significantly lower at the delayed primary attack than at the subsequent relapse. In 65 patients followed for both, the median value for the delayed primaries was 730 parasites per cmm. against 1,980 parasites per cmm in the subsequent relapse. These parasite fever thresholds are much higher than those for the induced primary attacks in Pacific *vivax* (21 per cmm.) shown previously.

Analyzing the same group of patients, London, *et al.* (1946), found that the delayed primary attack usually was indistinguishable clinically from later relapses. They believe, however, that the parasites and symptoms of the primary attack respond less readily to treatment than do the relapse attacks.

Response to treatment. The foreign malarias respond readily to adequate treatment. Of the commonly used drugs, chloroquine is best, quinacrine next, and quinine the poorest (Most, *et al.* 1946).

In relapse attacks, Most, *et al.* (1946), found only 2.1 per cent of 244 patients had fever the day after treatment or subsequently when treated with chloroquine as compared to 8.0 per cent of 391 attacks treated with quinacrine and to 8.7 per cent of 184 attacks treated with quinine. Chloroquine also cleared parasites from the blood stream faster than quinacrine or quinine; the percentages of patients cleared after 24 hours were 38, 26, and 9 respectively. In general, the rate of parasite clearance was grossly related to the initial parasite density.

Gordon, *et al.* (1945), also found that relapsing *vivax* from the Pacific was controlled promptly by quinacrine.

In cases of delayed primary attacks, London, *et al.* (1946), found the fevers and parasitemias less readily controlled by chloroquine than in the relapse attacks.

Treating the primary attacks of induced malaria with chloroquine, we (Young and Eyles, 1948) found only three of 17 patients had fevers 24 hours or later after treatment was started. Even though high parasite densities prevailed, 74 per cent of the parasites were removed in 24 hours and over 99 per cent in 48 hours. One patient was cleared of parasites by the end of 24 hours and all were cleared by the end of five days. There was a positive correlation between the parasite densities and the time to clearance of parasites.

Engstrom, *et al.* (1947), found that patients with primary attacks of induced malaria were cleared of parasites slower with quinacrine than were relapses in soldiers. They relate this to the higher parasite densities in the former.

We (Young and Eyles, 1948) could find no positive correlation between the number of paroxysms experienced in the induced primary attack and the rapidity of clearance of parasites from the blood stream upon treatment.

Sodium bismuth thioglycollate showed a selective action against parasites which were about half grown. An injection of 0.1 gm. of this drug usually removed enough parasites of this age so that that brood failed to cause fevers subsequently. In this, the response is similar to that of the St. Elizabeth strain (Young, *et al.* 1947).

Relapse rates. Young, *et al.* (1946), studying a random group of patients where the drug history was unknown or uncertain, found that 40 Mediterranean cases had averaged 7.1 relapses each and 117 Pacific cases had averaged 8.5 relapses each.

Most, *et al.* (1946), found that following treatment with quinine, quinacrine, and chloroquine, the relapse rate at the end of 120 days was 85, 80, and 70 per cent respectively. Other workers (Dieuaide, 1945; Gordon, *et al.* 1946b; Trager, *et al.* 1947) report similar relapse rates after quinacrine and quinine.

A smaller proportion of the Mediterranean malarias seemed to relapse than those from the Pacific. Most, *et al.* (1946), found from 70 to 85 per cent of Pacific *vivax* relapsing against 35 per cent of Mediterranean when treated by the same drugs, where both were observed for 120 days after treatment. Working with induced cases of malaria, Gordon, *et al.* (1946a), found 65 per cent relapses for Pacific and 13 per cent for Mediterranean cases after treatment with quinacrine.

Most relapses occur within 120 days following the last relapse.

The preceding relapse rates were obtained from soldiers having diverse malaria experiences such as length of exposure, different infecting dosages, possibility of infection with different strains, etc.

Craige, *et al.* (1947a), using a known Pacific strain (Chesson) under more controlled conditions showed a correlation with certain factors, viz., the greater the sporozoite inoculum, the shorter the prepatent period, the greater the relapse rate and the shorter the interval between relapses.

A domestic strain of *P. vivax* (St. Elizabeth strain) also shows a high relapse rate after treatment with quinine or quinacrine (Coatney, *et al.* 1948a). There are differ-

ences between this strain and the Pacific strains in relapse patterns. It is probable that the latter may show more relapses per person.

Relapse intervals. The intervals between clinical relapses appear to vary according to the drug used, being shortest for quinine, then quinacrine, and longest for chloroquine.

In 292 patients Eyles and Young, (1948), found the median interval to be 59 days (mean 61.6 days). The intervals were measured as from onset of one attack to onset of the next attack. Studying 500 attacks of Pacific and Mediterranean malarias where the interval was measured from completion of treatment to the next attack; Most, *et al.* (1946), found the median intervals to relapse to be: quinine, 24 days; quinacrine, 50 days; and chloroquine, 61 days.

One of the characteristics of the Pacific malarias is the prompt relapse after treatment of either a primary attack or a relapse. In contrast, a domestic strain (St. Elizabeth) when the primary attack or early relapse is treated adequately, shows long latent periods of 6 to 10 months before clinical reactivation. However, when late relapses begin they recur promptly until the end of the infection (Coatney, *et al.* 1948b).

Parasite density at clinical relapse. In over 800 clinical relapses, the median parasite density at the fever threshold was 3,200 per cmm. (mean 6,300 per cmm.) (Eyles and Young, 1948). The Mediterranean cases showed a significantly higher parasite fever threshold (median 3,836, mean 7,250) than the Pacific cases (median 2,952, mean 6,030).

No significant variation in parasite level was found between early, middle or late relapses in either the Pacific or Mediterranean group. Also, patients with high or low parasite densities during one clinical relapse tended to have high or low densities, respectively, during a subsequent relapse. Furthermore, those with low parasite densities at one relapse relapsed in similar proportions as those having high parasite densities.

Parasite patterns. The activity of the parasites in the blood stream of relapsing patients showed definite patterns in cases where each clinical attack was treated (Eyles and Young, 1948).

The most common type was the appearance of parasites a few days (average 3.5) before the onset of fever which increased in number until fever was produced. This type of parasitemia was called "preclinical asymptomatic parasitemia" and occurred in 77 per cent of the relapse attacks.

About 12 per cent of the cases showed parasitemias between typical clinical attacks, which were designated "interval asymptomatic parasitemias". These parasitemias occurred about 56 days after the onset of the preceding attack, were of low density (270 per cmm.), persisted an average of 12 days, and disappeared without ever provoking typical fevers. The next clinical attack followed about 24 days later.

A third pattern was the appearance of parasitemias after the final clinical attack which were called "terminal asymptomatic parasitemias". These occurred in 25 per cent of the cases. The parasitemias were of a low density and provoked no symptoms. They occurred about 80 days after the last clinical attack and persisted for an average of 44 days, during which time they fluctuated in density, often being

remittent or intermittent. The parasitemias gradually became lower and disappeared.

Both the Pacific and Mediterranean cases were similar in the above patterns.

Relative prevalence of parasitemias. A group of 200 patients whose clinical relapses were promptly treated were followed for 120 days to determine the proportion of time that parasites were present in the peripheral blood. The time includes the three types of parasitemias (Eyles and Young, 1948).

During the 120 days, parasites were present in patients with Pacific malaria 16.8 days (13 per cent of the time) of which only 3.9 days (3 per cent of the time) were symptomatic. For the Mediterranean patients, parasites were present 12.9 days (10 per cent) of the 120 days during which only 2.8 days (2.3 per cent of the time) were symptomatic. The difference between the Pacific and Mediterranean cases is probably due to the higher proportion of Pacific cases relapsing.

Seven relapsing patients who did not receive treatment of a clinical relapse were followed to determine parasite behavior. In spite of previous relapses, most of these had extended clinical activity. Terminal asymptomatic parasitemias occurred in all with remittent parasitemias which tended to exhibit lower densities with each recurrence. One patient who had had five relapses previously experienced intermittent clinical relapses for 90 days and on the 300th day of observation still had a low grade parasitemia. The infection in this patient was estimated to be 26 months old at the end of the observation.

In these cases, the proportion of the time of parasitemia was much greater than the 10-13 per cent found in those whose clinical attacks were promptly treated.

The production of gametocytes. In induced cases of foreign malarias, gametocytes were found in routine smears (examination of 0.1 cmm. of blood), at the time of first febrile attack in 2.0 per cent of the cases (Eyles and Young, 1948). At that time the number of gametocytes was low and became more prevalent as the disease progressed, reaching fairly high levels during the second week of parasitemia.

In the delayed primary attacks, 22.5 per cent of 200 cases showed gametocytes at the first fever.

In relapses at the time of the first fever, 35.2 per cent of 844 cases from both the Mediterranean and Pacific areas showed gametocytes, being significantly higher in the Mediterranean cases (55.7 per cent) than in the Pacific cases (29.4 per cent). The median density of the Mediterranean cases was 110 male gametocytes per cmm. as compared to a median of 80 per cmm. for the Pacific.

During the symptomatic and asymptomatic parasitemias, similar ratios of gametocytes to total parasites were found. This does not agree with the idea expressed by some that proportionately more gametocytes are produced during the asymptomatic parasitemias (Christenson, *et al.* 1946).

THE PARASITE IN THE MOSQUITO

Stage of disease in man and infection in the mosquito. Mosquitoes were infected by every stage of the disease showing parasites in the blood stream, viz., primary clinical attacks, delayed primary clinical attacks, relapse clinical attacks, and asymptomatic parasite relapses. Patients who had experienced 25 relapses, and others who had had

the disease for 33 months, produced infections in mosquitoes. As long as the patient had an overt malaria infection, the vectors might become infected (Young, *et al.* 1946; Eyles, Young and Burgess, 1948).

The ability of a patient with foreign malaria to infect susceptible mosquitoes seems to be a function of the number of parasites, and consequently the number of gametocytes, present in the peripheral blood stream. This general statement, of course, showed some exceptions. As has been a rather common experience, occasionally patients with low gametocyte counts would infect mosquitoes when others with higher densities would not (Moore, *et al.* 1945; Young, *et al.* 1946). Some patients seem to be better infectors than others. Also, a patient might infect mosquitoes at one time and not at another time, even though the latter instance might seem more favorable. But in the overall picture, higher parasite densities produced more infections in mosquitoes.

In one study, patients showing parasite relapses not accompanied by symptoms infected mosquitoes but at a rate (12 per cent) lower than the parasite relapses accompanied by symptoms (25 per cent) (Eyles, Young, and Burgess, 1948). This is further borne out by a demonstration in the same patient who during an asymptomatic parasitemia infected six per cent of the mosquitos fed upon him as against 87 per cent of the mosquitoes infected when fed during a symptomatic parasitemia.

Furthermore, the higher parasitemias which accompanied the symptoms produced heavier infections (more oocysts per gut) in the mosquitoes than did the lower parasitemias which were not accompanied by fevers.

However, even in the patients whose relapse attacks were treated promptly, the asymptomatic parasitemias were present for longer periods of time (average 12.2 out of a total 120 days) than were the symptomatic parasitemias (average 3.6 days out of 120). In patients whose clinical attacks were not treated, the discrepancy was even greater. Besides, the ill patient was less likely to be exposed to mosquitoes than the asymptomatic patient. Because of these factors, the patients with parsitemias without symptoms might be more likely to spread the disease than those showing symptoms.

Susceptibility of various species of mosquitoes. The infectivity of various foreign malarias showing clinical relapses in returned troops to the two important mosquito vectors is shown in Table 1. These data include the 238 cases previously reported (Moore, *et al.* 1945; Young, *et al.* 1946) and additional information obtained subsequent to those reports.

Malarias from widely separated areas infected American anophelines. The overall infection rate for 6,509 *A. quadrimaculatus* was 31.5 per cent and for 4,562 *A. m. freeborni* was 38.0 per cent. Of the 179 lots of *A. quadrimaculatus* fed, 62.4 per cent showed some infected specimens; of 103 lots of *A. m. freeborni*, 73.3 per cent showed infections. As these feedings composed a fairly representative sample, it indicates that if a relapsing patient is exposed to either of the principal vectors, the chances are that about two out of three times he would infect some of the mosquitoes.

It was also shown that the asymptomatic parasitemias would infect *A. quadrimaculatus* (Eyles, Young, and Burgess, 1948). Out of 2,059 mosquitoes, 11.6 per cent were infected. Of the 118 separate lots fed, 28 per cent had infected mosquitoes.

The lower infectivity of the asymptomatic group as compared to the clinical relapsing group is correlated with the lower gametocyte density in the former group.

No evidence was found that the malaras from any one area were significantly more infective to our important vectors than those from another area.

But it was found that the different anopheline mosquitoes, tested under identical conditions, possessed different innate susceptibilities to the foreign malaras (Young, *et al.* 1946; Young and Burgess, 1948).

TABLE 1

Summary of A. quadrimaculatus and A. m. freeborni fed upon troops showing clinical relapses of foreign P. vivax malaria

ORIGIN OF INFECTION	<i>A. quadrimaculatus</i>			<i>A. m. freeborni</i>			TOTAL BOTH SPECIES		
	Mosquito Lots Fed	Individual Mosquitoes		Mosquito Lots Fed	Individual Mosquitoes		Mosquito Lots Fed	Individual Mosquitoes	
		Dissected	Per cent Infected		Dissected	Per cent Infected		Dissected	Per cent Infected
Solomon Islands	76	2,912	27.1	49	2,280	38.1	125	5,192	31.9
New Guinea	53	2,008	34.0	42	1,986	39.1	95	3,994	36.5
New Britain	—	—	—	1	28	60.7	1	28	60.7
Subtotal South Pacific	129	4,920	29.9	92	4,294	38.7	221	9,214	34.0
Mediterranean	41	1,306	38.9	7	137	26.8	48	1,443	37.0
Liberia	1	47	21.3	1	32	40.6	2	79	29.1
C-B-I*	2	89	42.7	2	77	35.1	4	166	39.2
Caribbean	6	147	13.6	1	22	18.2	7	169	14.2
Total	179	6,509	31.5	103	4,562	38.0	282**	11,071	34.1

* China-Burma-India theater, probably Burma.

** In some cases multiple feedings were made upon one patient, so that 282 feedings were made upon 272 patients.

A comparison of the susceptibility to foreign *vivax* malaras of five anophelines showing the theoretical percentages of infection where the most susceptible species would show a 100 per cent infection has been postulated as follows (Young and Burgess, 1948):

Species	Theoretical Infective Index	Remarks
<i>A. m. freeborni</i>	100	Considered principal vector on West Coast
<i>A. punctipennis</i>	86	
<i>A. quadrimaculatus</i>	84	Considered principal vector in Southern States
<i>A. p. pseudopunctipennis</i>	41	
<i>A. albimanus</i>	2	Suspected as a vector in Lower Rio Grande Valley area

A. quadrimaculatus was used as the standard of comparison. With the exception of *A. punctipennis*, each of the species varied significantly from *A. quadrimaculatus*. *A. m. occidentalis* and *A. p. franciscanus* from the West Coast were compared to *A. m. freeborni* and appeared to have about the same susceptibility, although the numbers tried were not large enough to be significant.

It was further shown that different strains of *A. quadrimaculatus* exhibited a similar susceptibility to the same strain of malaria (Young, *et al.* 1946).

The malaria parasites showed a normal development in the various mosquitoes. In the only cases where abnormal sporozoites were produced, a fungus infection in the mosquitoes seemed to be the cause rather than any inherent mosquito-parasite relationship.

Some of these foreign strains have been maintained through many man-mosquito transfers. Although the mosquito used was different from the vector in the country where the malaria originated, the virulence of the malaria was maintained. This demonstrates the ease with which the *vivax* plasmodium adapted itself to new mosquito hosts.

Intensity of the infection in mosquitoes. Data on the number of oocysts per gut, involving both *A. quadrimaculatus* and *A. m. freeborni* which had been infected upon relapsing clinical cases, were tabulated for 1,520 specimens. Half of these had 10 or more oocysts per gut. Nineteen per cent had 100 or more oocysts per gut, which is a heavy infection. A few of each species of mosquitoes showed extremely heavy infections, having up to 800 oocysts per gut.

The number of sporozoites in the glands for 1,373 specimens, involving both mosquito species, showed 48 per cent with more than 100 sporozoites in the glands and 24 per cent with more than 1,000 sporozoites per gland.

For 239 *A. quadrimaculatus* infected upon patients with asymptomatic parasitemias, the mean number of oocysts per gut was 14.8. This is a lower oocyst density than was found in the mosquitoes which had been fed upon clinical cases.

Length of the sporogonous cycle in mosquitoes. The length of the sporogonous cycle is the number of days from the infective feeding to the first appearance of sporozoites in the glands; the latter is presumably the first day that the mosquito is able to transmit the infection.

Kept at about 75°F., this averaged 10.1 days for the *A. m. freeborni* and 10.7 days for the *A. quadrimaculatus*. Further tests will be needed to determine if this difference is significant (Moore, *et al.* 1945; Young, *et al.* 1946).

Influence of temperature upon infection in mosquitoes. Some infected lots of mosquitoes, both *A. quadrimaculatus* and *A. m. freeborni*, were divided and half of the mosquitoes kept at fluctuating outside temperatures with the other half at 75°F. The number of infected mosquitoes was about the same when the outside temperatures were high enough to allow development. The only difference noted was a lengthening of the time of the sporogonous cycle when the outside temperatures averaged less than 75°F.

Being incubated at outside temperatures averaging 59°F. for 19 days did not prevent the subsequent development of infections in *A. m. freeborni* when placed in a higher temperature (Moore, *et al.* 1945).

DISCUSSION

Many of the factors involving the host-parasite relationships between foreign *vivax* malarias and their hosts have been investigated. Where possible the foreign malarias have been compared with each other and with native malarias.

Malarias from the Pacific and Mediterranean areas appeared to be similar in the following points: relative lack of infectivity to Negroes, patterns of parasite relapse and infectivity to native vectors. The Mediterranean malarias had a higher gametocyte density and a higher parasite level at clinical relapse than the Pacific malarias. However, the Pacific malarias showed a higher proportion of patients relapsing after treatment and a greater relative prevalence of parasitemia than did the Mediterranean malarias.

From these criteria, the Pacific malarias might be considered as being more virulent in man than the Mediterranean malarias.

The foreign malarias seem to resemble native malarias on points such as morphology, infectivity to native white population, the course of the disease in the primary attacks, the lack of immunity between strains, the satisfactory response to adequate treatment, the ability to infect our native vectors and to be transmitted by them.

They differ from known domestic strains of *vivax* malaria in the following points, which might be considered as indicating greater virulence of the former: relapse more promptly after treatment of primary attacks, a tendency to produce a greater number of relapses, and possibly shorter prepatent and incubation periods in the human host.

Certain other biological factors of the foreign *vivax* malarias revealed were: None of the infections with tertian occurrences of fevers showed a periodicity of 48 hours but rather one that was shorter; the tendency for patients to show several types of parasitic relapses without being accompanied by symptoms, which resulted in the total time of asymptomatic parasitemias being considerably greater than the time of symptomatic parasitemia; the production of gametocytes in a rather constant ratio to the total number of asexual parasites; the ability of various foreign strains to similarly infect any one species of native mosquito even though the vector was a different species from the vector in the country of origin; the maintenance of virulence after many passages through the new insect vector; the difference in susceptibility of different species of mosquitoes to any one foreign strain; and the ability of the foreign malarias to develop in native mosquitoes under conditions similar to those in nature.

Epidemiological considerations. The overall picture of the foreign *vivax* malarias indicates they are as virulent as our native malarias, if not more so. They have shown every prerequisite necessary to establish themselves in this country. What then has been the result of their importation into this country?

It has been estimated that there were about 500,000 hospital admissions for malaria in the Army, most of which were overseas (Simmons, 1947). Although the definite number is not known, many of these relapsed with *vivax* malaria after returning to this country.

According to the morbidity report of Hampton (1946), of the 61,707 cases reported in this country for the year 1945, 19,847 (32 per cent) were of foreign origin. The

latter must have been almost entirely *P. vivax*. Of the 41,671 native cases, there was no breakdown as to species.

An attempt was made to determine the proportion of *P. vivax* in native cases during 1945 by requesting information from Boards of Health in southern states. With the exception of South Carolina, no state had laboratory diagnoses as to species based upon surveys. In South Carolina, four per cent of 1,137 positives found in a survey were *P. vivax* (McDaniel, 1948).

Thus, the data received indicated that the proportion of *P. vivax* in native cases for 1945 might range from four per cent to nearly 100 per cent of the reported cases. So if we arbitrarily assume that about one-half of the native cases reported in 1945 were *P. vivax*, this means that for that year there were about as many foreign cases (19,847) as native cases (20,835) of *P. vivax* present. In other words, the introduction of foreign malarias might be estimated to have doubled the incidence of *vivax* malaria reported for the year 1945.

Faust, *et al.* (1947), estimates that relapsing malaria cases from overseas were dispersed to practically every county in this country. We have shown the native vectors to be good vectors of foreign malarias. Thus, the natural potentialities for the foreign *vivax* strains to become established are great.

Because of the virtual impossibility of distinguishing foreign from native *vivax* malarias, foreign malarias would not be detected by the ordinary blood smears. In areas where there is little malaria now, outbreaks due to importation of foreign strains would be fairly obvious. In fact, such has already been reported (Osgood, 1945). However, the same factors which prevent the occurrence of native malarias in those areas would reduce the likelihood of new strains being established.

The greatest possibility of foreign malarias being spread is in areas such as the South where factors such as abundant vectors, long breeding seasons for mosquitoes, poorer housing, lower economic standards, etc., have allowed the persistence of malaria for many years. And it is in such areas that the spread of foreign malarias, except under unusual and rare circumstances, could not be detected. The result is that probably we shall never be able to determine accurately how much the foreign malarias have and will become established.

But from the knowledge gained of the foreign malarias, we can predict certain occurrences. It is virtually certain that some, if not many, of these foreign strains of *vivax* have and will become established, as every natural requirement is fulfilled. As these foreign strains are immunologically distinct, it means that no protection is gained by previous infections with native malarias. Any one person is susceptible to a potentially greater number of strains of *vivax*, which increases the magnitude of the problem.

It has been a common experience in the past in this and other countries that after wars where troops returned from malarious areas, outbreaks occurred in new areas and often persisted for a number of years. Such has occurred in other countries after World War II (Stevens and Blackman, 1946; Vogt, 1946; Beklemischer, 1946; and Hernberg, 1947).

That such has not been so dramatic here after World War II may be ascribed to various factors, such as improved handling of malaria cases including better treatment, better economic conditions, and better and more extensive malaria control.

Probably the most important factor by far is that these malarias were imported during a time when the malaria rates were declining due to natural or man-made causes (Andrews, 1948).

Should extensive migrations occur before our methods of controlling malaria in man or in nature are universally extended or radically improved through the discovery of even more efficient insecticides or the finding of a truly curative drug, we can expect additional strains to be added to those already present in this country.

Other results of program. To test the susceptibility of *A. m. freeborni*, a supposedly important vector, it was necessary to colonize this species on a large scale, which had never been done before. Hardman (1947) developed methods by which it is possible to rear large quantities of this species. As a result it is now possible to study this species of mosquito under experimental conditions.

Methods were developed also which insured the reliable and rapid biting of mosquitoes at a desired time (Burgess and Young, 1944, and unpublished data). This was a very important factor in testing large numbers of mosquitoes against foreign and domestic malarias to evaluate vectors. This was important also in the cooperative programs where a search for better antimalarial drugs is underway as it made possible the mass production of malaria-infected mosquitoes which could be depended upon to infect patients at the desired time (Coatney, *et al.* 1948a).

Furthermore, a strain of South Pacific *vivax* malaria (Chesson) was isolated and has been extensively used in the search for better antimalarial drugs and improved methods of treatment of malaria (Ehrman, *et al.* 1945; Gordon, *et al.* 1946a; Craige, *et al.* 1947b; Shannon, 1945-46; Coatney, *et al.* 1948a).

Foreign malarias were found to be efficacious as an agent in the treatment of neurosyphilis (Young, *et al.* 1947). In fact they have some advantages over indigenous strains as some patients were refractory to the latter because of a previous infection with native malarias.

SUMMARY AND CONCLUSIONS

1. The program on foreign *Plasmodium vivax* malarias had been carried out by studying the infections in returned troops, by inducing these malarias in other patients, and by feeding large numbers of mosquitoes on malarious patients.

2. The infections in man were quite similar in many respects to domestic malarias but showed a few characteristics which might indicate they are more virulent.

3. Certain factors in the life cycle of the foreign malarias were pointed out, among which was the tendency to show parasitic relapses to a greater extent than clinical relapses.

4. These malarias readily infected our native malaria vectors and were transmitted by them. Malarias from different parts of the world showed similar infectiousness to the same species of domestic vector. Different species of mosquitoes did not show similar susceptibilities to the same strains of foreign malarias. The most dangerous domestic vectors were also the most susceptible to the foreign malarias.

5. The foreign malarias in man were infective to mosquitoes during both symptomatic and asymptomatic parasite relapses, being most infective during the former. Gametocytes were produced in a rather constant ratio to the total number of parasites present. Mosquito infections were heavier during clinical attacks but it was

shown that mosquitoes might be infected whenever a sufficient number of parasites were present.

6. The patient with an asymptomatic parasitemia is considered the one most likely to spread the disease.

7. It is estimated that during 1945 there may have been in the United States as many cases of foreign *P. vivax* as there were cases of domestic strains.

8. It is concluded that as a result of the foreign malarias returned by troops, many new strains of *vivax* malaria have been added to those already indigenous to this country and that these new strains will be propagated equally as well. Except in rare instances, there will be no way to distinguish between the native and imported strains in nature.

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DUCKS AS MOSQUITO PREDATORS

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In the course of entomological investigations in relation to malaria control in Dougherty County, Georgia, we observed in the summer of 1946 a rather unusual, if not novel, instance of avian predation on mosquito larvae.

Through routine observations, we were aware that a certain pond situated on Maridor Plantation supported a particularly dense larval population of *Anopheles quadrimaculatus*. Many larvae of *Anopheles crucians*, *Culex* and *Uranotaenia* species were also found in association. This pond is designated as No. 18-19 on the Dougherty County Malaria Control Map, and it measures approximately 1.5 acres in extent. Vegetation and flottage covered the entire surface, and thus provided extensive areas suitable as larval habitats. Larval densities in this pond increased throughout the summer until a maximum of 35 per square foot of breeding area was observed on October 1. A few days later the overseer of the plantation turned a flock of exactly 93 large White Peking ducks into the pond to graze. Ten days following, when the pond was next included in our observations, not a single mosquito larva could be found. All edible flottage had also disappeared. Presumably, the ducks had performed a thorough job of eradication, and, since the birds remained in the pond, no more larvae were found on subsequent inspections.

The continued presence of large numbers of larvae in comparable ponds attests that the disappearance of larvae from the pond in question may not be attributed to seasonal decline in breeding. No larvicides were applied to the pond at any time during 1946.

Inasmuch as this pond is the only important "quad pond" within flight range of the human dwellings on the plantation, it would appear that the feeding activities of the ducks had resulted, locally, in an appreciable contribution to malaria control.

We can find no reference to ducks as predators of mosquito larvae in the literature devoted to naturalistic methods of control. However, in a series of articles on wild ducks currently appearing in *Sports Afield*, B. W. Cartwright (Chief Naturalist, Ducks Unlimited) states that the Mallard Duck ingests substantial quantities of mosquito larvae. Since their sojourn in the South is largely restricted to the winter months, it is obvious that the predations of wild ducks on mosquito larvae are of little significance in the malarious regions of the South.

It would be interesting to know whether or not other field workers have observed instances of predation similar to the one described above.

A REVIEW OF CURRENT GEORGIA MALARIA CONTROL OPERATIONS¹

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Since the discovery of its method of transmission, efforts to control and reduce the incidence of malaria have been ever-changing. Georgia has experienced all phases of control operations from drug prophylaxis to major drainage. Although considerable progress was made in drainage of anopheline breeding areas near human concentrations, and an organized program was established for the clearing and maintenance of hydro-electric impoundments, no mass program of drainage was undertaken until Federal relief funds made this possible. It was during this period, through the facilities furnished by the RFC, CWA, FERA and WPA (1933-41), and with the cooperation of the U. S. Public Health Service, that the State was able to put primary emphasis on major and minor drainage construction, including monolithic and pre-cast invert paving and other semi-permanent features.

The mobilization of troops prior to World War II was the signal for a radical change in malaria control. The need for the protection of military personnel brought into existence the MCWA (1942-1946), a new operating agency of the USPHS, which furnished personnel, materials and equipment to the States for whatever measures were needed. The emphasis was then shifted to larviciding and minor drainage operations about war establishments and places frequented by military personnel. Georgia MCWA operations have been previously reported (Lenert and Legwen, 1943).

With the cessation of hostilities and the demobilization of troops, malaria control operations again underwent a radical change. Many returning infected soldiers were released throughout endemic malaria areas where it was supposed the prevalence of the insect vector would provide ideal conditions for epidemic malaria in the civilian population. Preparation for meeting this impact was made possible through the release by the Army to the USPHS of a limited amount of DDT for residual spraying of homes in a selected group of counties in 1945. This review will be confined to the residual spraying operations performed during 1945, 1946 and 1947 and those planned for the 1948 season, all made possible by the CDC, the operating agency succeeding MCWA in 1946. This is known as the Extended Program of Malaria Control.

ORGANIZATION

The State Director of the Malaria Control Program maintains liaison with the CDC Headquarters and is responsible for general plans and policies. All CDC personnel used on the program serve as employees of the State and of the local health departments, with technical supervision furnished by the Engineering Division of

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the State Department of Public Health. Preliminary negotiations with county boards of health or commissioners are performed by or under direction of the State Director.

The Administrative Section, made necessary by the decentralization of Federal facilities through the states, was continued as organized under MCWA. Since 1946, this Section has served the Typhus Control Program as well as the Malaria Control Program. This Section, with the Operations Assistant, constituting what is referred to as the State office, is the direct responsibility of the Assistant State Director, who also directs all field operations and State Warehouse facilities.

In 1945 field operations in fourteen counties were directed through four Area Supervisors.

In 1946, 37 counties were grouped in 14 areas and 3 districts.

In 1947, 51 counties were grouped in 16 areas and 4 districts.

FINANCE

Originally scheduled for operation in 1945 were three entire counties and parts of eight others where malaria incidence was considered greatest. The entire costs in those areas were from federal funds. The public demand for the program was so insistent that operations were extended to the remainder of four of the original group and to three additional whole counties (totaling 14 in all); the local authorities furnishing fifty per cent of additional labor costs and spray equipment. Further expansion during 1945 was limited by the amount of DDT available.

In 1946, working under a limited allocation with a tremendous demand for the program, a proposal was worked out and accepted under which the county furnished crew personnel, one vehicle and its operation cost for each crew, warehouse and office facilities. For the calendar year, county financial participation amounted to \$121,774 or an average of \$0.77 per house spray application.

In 1947 local participation was increased by all multi-crew counties also furnishing the contact personnel (assistants) and their transportation. County financial participation for the calendar year totaled \$171,046 or \$.78 per house spray application.

For 1948 local participation will be the same as in 1947 plus funds for minor purchases and one-crew counties will provide personnel for contact work or the financial equivalent.

One Supervisor was employed for each county, area and district. In each county unit, one or more crews of one to three men each, performed spraying operations. In multiple-crew counties, an Assistant was employed for each two crews. The duties of the Assistant consisted of securing and posting census and sanitation survey data from each inhabitable house in the county; explaining to the householder the purpose of program; securing request of the householder to participate; advising necessary preparations to be made prior to crews arrival and approximate time of arrival; laying out routes for the spray crews in accordance with County Supervisors' instructions; installing or replacing house numbers and currently correcting county map. In one-crew counties, these functions are performed by the County Supervisor in addition to his responsibility for maintenance of vehicles and equipment,

delivery of supplies, supervision of spray crew, local publicity, contacts with local officials and civic groups, etc.

Although there is no direct appropriation, the State Department of Public Health has furnished and will furnish services of the State Director, cartographic and drafting personnel, printed forms and maps, office supplies and various miscellaneous items.

Federal funds have been used for all other authorized operations, including all DDT and allied chemicals; all supervisory services, other than those of the State Director; transportation of supervisory personnel; necessary spray equipment; state warehouse facilities and items not specified as being furnished locally.

It should be noted that local participation has been provided by county authorities and not by funds collected from individuals by extended program personnel. Generally, local funds to provide the necessary elements of participation have been derived from tax sources, though some few counties have secured their funds by public or private subscription. *In no case* has a householder been refused the residual spraying service because he did not directly contribute to the local costs of the program.

EQUIPMENT

In 1945, with one exception, operations were begun with the equipment and procedures developed or specified by the U. S. Public Health Service personnel assigned to the Carter Memorial Laboratory. The single exception was that emulsion was mixed in 30 to 50 gallon batches, rather than in 1 to 2 gallon batches. Hand sprayers, equipped with built-in pumps and 80-02 nozzles, and power sprayers were used initially. Considerable difficulty was encountered in maintaining airtight gaskets, due to the deleterious effects of the DDT solvent (Xylol) and considerable maintenance was required for the spray pumps. In addition, it was difficult to retain spray crew personnel, due to the manual labor required for the frequent hand pumping necessary to maintain satisfactory air pressures in the hand sprayers.

In June 1945, a 40 gallon heavy duty hot water tank was secured and converted to a compressed air tank by the addition of plugs; air filling valve; air gage; shut off valve; hose; and automatic chuck. The pumps were removed from several hand sprayers and air filling valves then installed in the sprayers. After loading the compressed air tank to a pressure of 135-150 psi, it was used to load each hand sprayer to a pressure of 50 psi. Field tests soon revealed that a production gain of approximately 25 per cent could be effected by this method as compared to hand pumping operations.

Additional air tanks were difficult to acquire, but by September, 1945, all spray crews were equipped with air tanks and hand sprayers were modified with air filling valves. At no cost, these air tanks were filled each morning by a service station air compressor. With the modified hand equipment, spraying operations consistently could be performed faster than with the power sprayers which were then withdrawn from use.

In 1946, all crews were provided with the air tanks and modified hand sprayers. While this equipment was greatly superior to that originally furnished and utilized, it still retained several objectionable features. The ring type head gasket was diffi-

cult to maintain; a constant air pressure could not be maintained with the single compartment sprayer, as the air pressure decreased as the emulsion was discharged; some crew members had a tendency to use excessive initial air pressures in order to discharge all of the emulsion without restoring air pressure.

In July 1946, a sprayer was designed which eliminated the objectionable features of the sprayers in use at that time and it was designated as the "Regulated Pressure" sprayer. (Figure 1.) It was composed of two 500 cu. in. (approximately $2\frac{1}{6}$ gals.) tanks (surplus Air Force type, designed for working pressures of 400 psi), one of which was used for air storage and the other for emulsion. An air filling valve was incorporated in the air tank which, through a regulating valve and shut off valve, was connected to the emulsion tank. The emulsion tank was equipped with a $1\frac{1}{2}$ " filling opening, whose cap could be removed by hand and in which was incorporated a solid type gasket. With the regulating valve set at 40 psi, and with an initial air tank pressure of approximately 85 psi, the entire contents ($2\frac{1}{6}$ gals.) of the emulsion tank could be discharged at a uniform pressure of 40 psi. With initial air tank pressure of approximately 125 psi, the emulsion tank could be twice emptied without reloading the air tank.

The emulsion tank was equipped with a $\frac{1}{4}$ -inch bottom discharge outlet. A $\frac{1}{4}$ -inch copper tube protruded from this outlet approximately $\frac{3}{4}$ -inch into the emulsion tank and thus allowed trash and other sediment to be retained in the tank, rather than enter the outlet hose and clog the nozzle strainer. The emulsion tank was washed out at the end of each day and if nozzle clogging occurred, the tank, outlet lines and nozzle were cleaned more often.

The tanks were set in a carrying frame, equipped with a handle and a carrying sling. Fully equipped, the empty sprayer weighed approximately 18 lbs. and when loaded, weighed approximately 35 lbs.

In operation, either tank could be filled first or both may be filled at the same time.

All crews were furnished 55 gal. emulsion tanks, equipped with strainer funnels for filling and with quick opening faucets for emptying. For nozzle separation, each crew truck was equipped with a $\frac{1}{16}$ -inch box wrench rigidly attached to the truck or accessory equipment. In operation, the nozzle cap was inserted in the box wrench and the nozzle body was easily loosened from the cap by means of a $\frac{1}{16}$ -inch open end wrench.

Crews were also equipped with extra long wands for spraying ceilings not accessible with ordinary wands of 18-inch to 30-inch lengths.

Tools for inserting tips in Hudson type cutoff valves were secured and furnished to each Area Supervisor who then replaced tips in the extra plungers previously furnished each crew.

WAREHOUSE EQUIPMENT AND PROCEDURES

In 1945, warehouse facilities for the Extended Program were established at Macon, Georgia and consisted of one building located on a railroad siding just beyond the western City limits. The building was used for storage of equipment, supplies and chemicals and the central mixing plant was operated outside, but in close proximity to the building. Concentrate was mixed in 43 gallon batches, utilizing the drum type

mixer developed by personnel of the Carter Memorial Laboratory. In November 1945, additional warehouse facilities were secured at the same location, in order to provide for the greatly expanded program. Three 5000 gallon storage tanks were secured, placed underground and interconnected for use in storing DDT solvents.

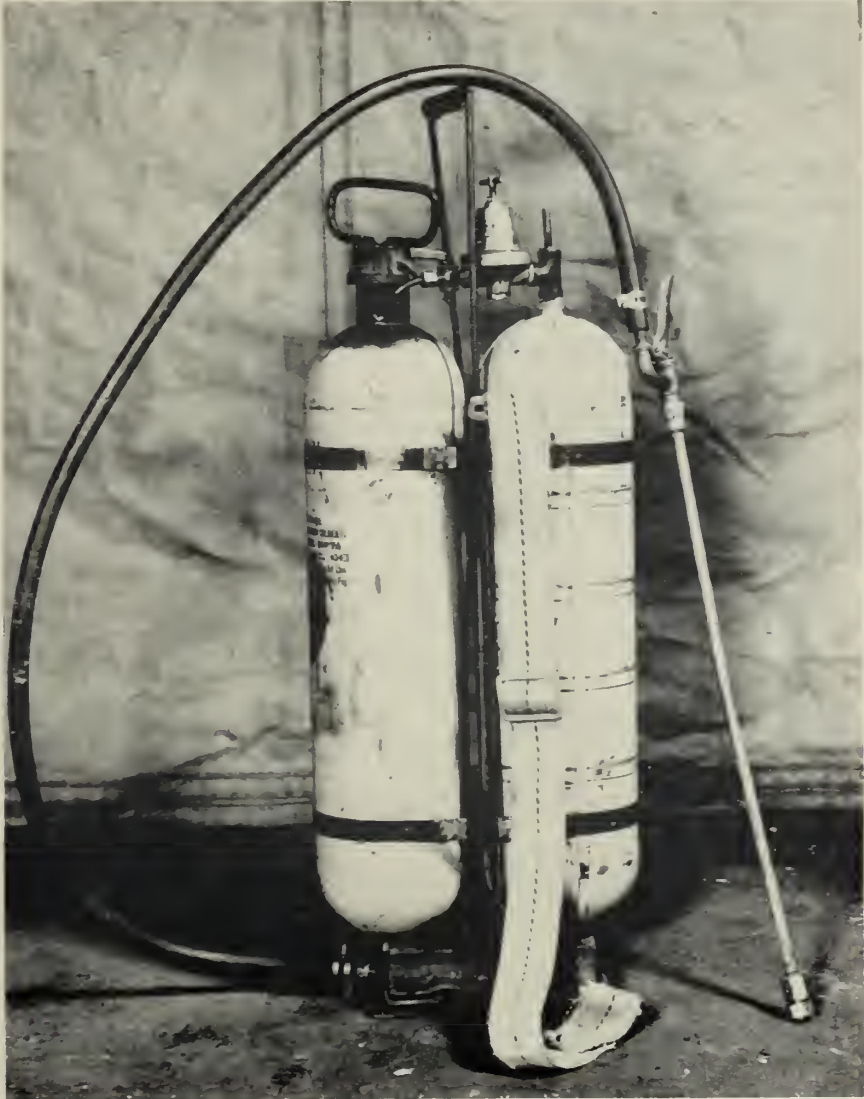


FIG. 1. THE "REGULATED PRESSURE" SPRAYER

A 250-300 gallon concentrate mixer of paddle wheel type was constructed and used for 1946 and 1947 seasonal operations. In 1947, a 350 gallon elevated concentrate storage tank was constructed so that concentrate containers could be filled by gravity flow and thus eliminate back pump pressures and consequent fire hazards.

In 1945 and 1946, concentrate was delivered to field stations in 55 gallon containers and in 1947 one gallon containers (packed 6 gallons to the crate) were used and proved more acceptable to field personnel.

State vehicle repair facilities were established at the Macon Warehouse in May 1946, employing one mechanic, a welder and from one to four helpers. In September 1946, these operations were transferred to Cochran Field (about 11 miles South of Macon) in order to secure larger repair shop facilities and better areas for winter storage of vehicles.

MATERIALS AND APPLICATION RATES

In 1945, 20 per cent and 35 per cent DDT concentrates were utilized and residual spraying operations were performed using a 100 mg/sq. ft. application rate by applying one (1) gallon of 2½ per cent DDT emulsion per 946 sq. ft. surface.

In 1946, 20 per cent and 35 per cent DDT concentrates were utilized. Operations through July 20 were performed at an application rate of 200 mg/sq. ft. For the remainder of 1946, application rates were reduced to 100–104 mg/sq. ft. since a simi-

TABLE 1
Comparison of toxicity of DDT at different rates of application

TEST NO.	APPLICATION RATE ON SURFACE TESTED	AGE OF APPLIED SPRAY	NUMBER OF FLIES EXPOSED	MORTALITY IN 24 HOURS	
				No. flies	%
	<i>mg/sq.ft.</i>	<i>weeks</i>			
1	100–104	10	328	314	95.7
2	143–147	10	314	302	96.2
3	100–104	14	360	285	79.2
4	143–147	14	337	272	80.7

lar application rate in 1945 had proved entirely satisfactory and the 100 mg/sq. ft. rate afforded a 50 per cent reduction in concentrate costs.

In 1947, with one exception, an application rate of 100–104 mg/sq.ft. was used in all counties. In July, Turner County Commissioners provided chemicals to increase the application rate to 143–147 mg/sq. ft. Toxicity tests have been conducted on surfaces sprayed in inhabited homes in Turner County with the two different application rates. Native houseflies were used in these tests and the equipment and testing procedures were identical to those developed at the Savannah Laboratory. Using an exposure period of 30 minutes and a holding period of 24 hours, tests results are shown in Table 1.

As may be noted from the entries in Table 1, the increase of 43 per cent in emulsion application rate produced an increase in killing rate of only 0.5 per cent after 10 weeks and only 1.5 per cent after 14 weeks. Georgia operations are conducted on 2 spraying rounds per season with an interval of 10–14 weeks between rounds. The 100 mg/sq. ft. application rate is considered satisfactory since it has been demonstrated that it will result in a mortality rate between 96 per cent and 79 per cent at the end of 10 to 14 weeks. The increase of 1 per cent to 2 per cent in mortality rates result-

ing from a 43 per cent increase in application rates does not justify the increase in chemical costs required.

Other toxicity tests have been conducted on surfaces sprayed with emulsion prepared from the War Assets Administration 25 per cent DDT concentrate and from 25 per cent and 35.7 per cent concentrates locally compounded with different solvents (Xylol and Toluol). No significant difference in toxicity has been noted for equal strength emulsion applications prepared from the various concentrates.

1947 SPRAY CREW PROCEDURES

Spray crew personnel were employed by local authorities and before operations were begun, underwent a two to three day training period conducted by an experienced and well-qualified supervisor. In this training period the crew personnel became thoroughly acquainted with all equipment that would be used in field operations; with crew organization and procedures; and before operations were commenced, each member demonstrated that he could uniformly and consistently apply the emulsion at the designed rate of application. In this regard, application rates on routine operations were frequently checked by the County, Area and District Supervisors to be certain that complete and uniform coverage was obtained.

The daily crew operations began at the County warehouse, where the crew truck was loaded with all necessary equipment and supplies, including one 50 to 80 gallon air tank with air pressure of 135 to 200 psi; one 55 gallon emulsion drum; 2 strainer funnels; 4 to 8 RP sprayers (at least 2/man) with one or more equipped with extra long wand; 1 set of scales (50-100 lb. capacity, 1 lb. graduations); two 10-14 qt. pails; day's supply of concentrate, stored in one gallon or 5 gallon containers; supply of field repair parts—nozzles, wands, hose, hose clamps, cutoff valve plungers, gaskets, valve cores; hand tools, including $\frac{1}{2}$ - $\frac{3}{8}$ -inch wrenches, pliers, small stillson wrench, monkey wrench, etc.; wiping cloths; and the daily report forms on which the day's spraying schedule was shown.

Before leaving the warehouse, a 30 to 55 gallon batch of emulsion was prepared, using the strainer funnel to strain the concentrate and water as the drum was filled. Additional emulsion was mixed during the day at locations where ample supplies of water were easily available. Loading operations and afternoon cleaning and unloading operations were on an organized basis, with each crew member routinely assigned to specified tasks.

At the first house to be sprayed, each crew member loaded his sprayer with air and emulsion, and to the nearest pound, recorded the weight of the loaded sprayer. One crew member was routinely assigned to spray outside surfaces (privy, porch, doors, etc.) before entering the house. Remaining crew members (1 to 2) were assigned to spray inside surfaces including walls and ceilings, closets, cupboards and mattresses and bedsteads where permissible. No spraying was authorized or performed at individual residences unless adequate preparations for the spraying had been made by the householder and unless all bedrooms were included in the areas to be sprayed. As each crew member completed his spraying, he returned to the truck and by weighing the used sprayer, determined the weight of the emulsion he had applied. This

emulsion weight was reported to the head sprayer who recorded the total weight of emulsion applied at the house, recorded the number of rooms, porches, mattresses and privies sprayed and to the nearest five minute interval, recorded the arrival and departure times at each work site. Hand sprayers were replenished with air and/or emulsion before leaving the spraying site unless such replenishment operations would delay the departure of the entire crew. The same procedures were followed at houses subsequently sprayed during the day, except for reloading the hand sprayers after the last house was sprayed.

On return to the warehouse, the emulsion remaining in the hand sprayers was returned to the emulsion drum; all hand sprayers used during the day were cleaned, including flushing the emulsion tank, hose lines and wands and thoroughly cleaning the nozzles. Equipment needing material repairs was reported to the County Supervisor and necessary replacement equipment secured. Equipment and supplies that could not be safely stored overnight on the truck were placed in the County warehouse. After completing the day's operations, the completed Sprayers Daily Report was delivered to the County Supervisor and route sheet for the following day secured.

After reviewing the daily operations reports, the County Supervisor posted and summarized these reports on the Weekly Operations Report, one copy of which was forwarded to each superior office.

OPERATIONS DATA

In 1945, 1946 and 1947 weekly operations reports were prepared and submitted by each County Supervisor. In addition to these reports being carefully reviewed by the respective Area and District Supervisors, a weekly summary of the reports was prepared at the Macon office and promptly distributed to all supervisory personnel. This summary was accompanied by a General Memorandum in which the Assistant State Director or the Operations Assistant constructively criticized the week's operations.

Operational averages which were considered significant included:

1. *Refused percentage:* The percentage of inhabited residences which were contacted but unsprayed. 1946 average 15 per cent, 1947—23 per cent. Percentage may be reduced by improving publicity and contact work. It arbitrarily increases in better class houses, particularly in suburban or urban areas. If only pest control spraying (outside and kitchen surfaces) were offered to householders, refusal percentage could probably be held below 10 per cent.

2. *Spray time percentage:* The percentage of spray crew time actually spent at spraying site. In 1946—66 per cent and in 1947—71 per cent. Percentage will vary considerably due to many factors, some of which are uncontrollable. These include: crew organization; density of population; travel conditions including crew vehicle, road system; weather; refusals after crew arrival; warehouse facilities, etc.

3. *Units sprayed per gross manhour:* The average number of dwelling units sprayed per spray crew *gross manhour* which includes all spray crew time, including maintenance, warehouse, travel, mixing and spraying operations time. In 1946—1.19 and in 1947—1.68. Considering this average alone, two man crews are slightly more

efficient than 3 man crews. However, travel and salary costs per man will be higher with 2 man crews, than with 3 man crews.

4. *Rooms sprayed per gross manhour*: Same as in Item 3 except computation is based on rooms. In 1946—5.36 and in 1947—7.65. Rooms per unit averaged 4.53 in 1946 and 4.55 in 1947.

5. *Gallons of emulsion per unit*: In 1946—2.6 and same for 1947. DDT application per unit in 1947 was 0.78 lbs.

6. *Gallons of emulsion per room*: Averaged 0.57 in 1946 and 0.57 in 1947. On weekly basis, an application average of less than 0.50 gallons was considered unsatisfactory.

TABLE 2

Georgia Extended Program of Malaria Control, 1946-1947
Summary of Operations and Cost Data

ITEM	CALENDAR YR. 1946	FISCAL YEAR 1947	CALENDAR YR. 1947
Number of County Programs.....	37	52	51
Number of Unit Sprayings.....	158,639	189,486	218,245
Average Gallons of Emulsion/unit.....	2.59	2.62	2.61
Average Pounds of DDT/unit (1).....	1.23	0.85	0.78
Average Number Square Feet Sprayed/unit.....	3,365	3,405	3,390
Average Units Sprayed/Spray Crew Gross MH.....	1.19	1.50	1.68
State and County Expenditures.....	\$138,774	\$170,784	\$194,546
USPHS—CDC Expenditures (2).....	388,146	338,642	334,207 (3)
Total Expenditures.....	526,920	509,426	528,753 (3)
State and County Cost/unit.....	0.87	0.90	0.89
USPHS—CDC Cost/unit.....	2.45	1.79	1.53
Total Cost/unit.....	3.32	2.69	2.42

(1) 200 mg/sq.ft. application rate in 1946 through July 23 and 100 mg/sq.ft. application rate in 1947.

(2) Includes all annual costs for malaria.

(3) Includes estimated costs for November and December.

7. *Gallons of emulsion per gross manhour*: Averaged 3.1 in 1946 and 4.4 in 1947. The theoretical and unattainable maximum was 12.0 (60 x 0.2) since output of hand sprayers was 0.2 gallons/minute under 40 psi. An average of 4.4 signified that the average sprayer's production approximated only 37 per cent of the theoretical maximum. In other words, approximately 63 per cent of this time was spent in operations that were incidental to, or non-productive, as far as actual spraying was concerned.

8. *Gallons of emulsion per spray manhour*: The average output of emulsion based on spray crew manhours spent at the spraying site. Averaged 4.7 in 1946 and 6.2 in 1947. The 1947 average indicates that the equivalent of 48 per cent ($12.0 - 6.2 = 5.8$; $5.8 \div 12.0 = .48$ per cent) of the time was spent in non-spraying operations after reaching the spraying site. With spray time correctly reported, this average is a direct measure of crew organization and operations at spraying site.

In table 2, operations data are given for calendar years 1946, 1947 and for fiscal

year 1947. The USPHS—CDC expenditures included all expenditures other than depreciation charges on automotive vehicles and minor office supplies furnished from Headquarters' warehouse stocks. With one exception, unit costs are computed on the basis of annual expenditures for all malaria operations, *including offseason operations*, divided by the number of unit sprayings completed during the specified year. The one exception is where DDT and allied chemicals were purchased in very large lots and not entirely utilized during the year of purchase, only the amounts actually used during the year were charged to that year's operations.

RESULTS

In 1945, operations in 14 counties met with practically unanimous approval of the citizens whose homes had been sprayed. In 1946, operations were conducted in 37 counties including the 14 counties sprayed in 1945. In the 1945 group, even though the initial 1946 application was twice as heavy as the 1945 applications, minor dissatisfaction was expressed. In the remaining 23 counties, practically all citizens were very well satisfied with all phases of the 1946 operations. In 1947, operations were conducted in 51 counties including 36 of the 37 counties sprayed in 1946 (Dooley County did not operate in 1947 due to its inability to furnish the required local participation. In response to the demand of local citizens for a resumption of the program, Dooley County authorities will participate in 1948). With the exception of one county of the group of 15 in which operations were first begun in 1947, operations met with the general approval of the public. In the other group of 36 counties, a fairly large number of complaints were received. In all counties, every specific complaint that was received by supervisory personnel was promptly investigated and in approximately 10 counties, tests were conducted to determine the toxicity of wall surfaces resulting from routine operations. For *all* tests (the majority of which were made in the residences of complainants) made within 14 weeks of the spray application, ample toxicity was demonstrated.

In our opinion, the majority of complaints were due to one or more of the following reasons:

1. The general public is far more critical of results of all applications subsequent to the initial application.
2. In 1947, breeding conditions were exceptionally favorable for flies and mosquitoes.
3. In too many instances, householders were very lax in maintaining proper household and premise sanitation, depending entirely upon the DDT residual spraying for insect control.
4. A misunderstanding of results to be expected from DDT residual spraying. Some persons apparently expected that after their residences were sprayed, *all* insects would vanish from their neighborhood.

In July of 1946, a public opinion poll concerning the program was taken among Health Commissioners, private and public physicians, county officials and other persons living in counties where residual spraying operations were being conducted. Results of this poll indicated:

1. Malaria morbidity was much lower;

2. Diarrhea and enteric diseases, particularly among children were greatly reduced;
3. Household insects were almost eliminated in number in following order: flies, mosquitoes, roaches and gnats;
4. Costs for family medical care were much less;
5. Living comfort was increased immeasurably.

In 1947, no general poll was taken, but informal inquiries revealed results generally similar to the 1946 poll. Distributors of insect spray and malaria medications have stated that their sales of these items have been practically eliminated in the program counties.

As is probably true in other states, reporting of malaria cases and deaths is very incomplete. However, the trend continues downward with 461 cases reported in 1945, 109 reported in 1946 and in 1947 only 59 cases reported through November 1. In 1948, measures are planned to encourage more complete reporting and treatment of malaria cases. Tentative plans include a \$10.00 payment to every person whose illness is diagnosed as malaria, provided; (1) The diagnosis is confirmed by Health Department blood smear examination; (2) The patient is treated by a licensed physician; (3) The patient is a Georgia resident and the infection is of Continental U. S. origin; (4) Full and prompt information is given concerning residence location, probable infection site and date.

In addition to epidemiological investigations and treatment of 1948 cases, each patient's home will be promptly sprayed. It is believed that the measures planned for 1948 will further accelerate the downward trend of malaria in Georgia and increase the possibility of its eradication in the not too distant future.

REFERENCE

- LENERT, LOUVA G. AND LEGWEN, W. A. 1943 State and Local Organizations for Malaria Control in War Areas. *Jour. Nat. Mal. Soc.*, 2: 2, p. 49-56.

PRESIDENT HINMAN BECOMES DIRECTOR OF HEALTH AT UNIVERSITY OF OKLAHOMA

Dr. E. Harold Hinman, President of the National Malaria Society and Chief of the Malaria Control Division of the Health and Safety Section of the Tennessee Valley Authority, has been appointed Director of Public Health at the University of Oklahoma, Norman, Oklahoma.

Dr. Hinman was born at Wicklow; Ontario, March 20, 1904. He received his B.A. degree (with honors) in 1927 at Queens University, and his Ph.D. in 1930 at Cornell University. From 1932 to 1937 he was Assistant Professor in parasitology and medical entomology in the Department of Tropical Medicine at Louisiana State University Medical School and received his M.D. degree at this school in 1937.

In the summer of 1937 he joined the staff of Malaria Studies and Control Division, Health and Safety Department, Tennessee Valley Authority, Wilson Dam, Alabama. During the academic year of 1941-42 he was on leave of absence from TVA for post-graduate work in public health under fellowship from the Rockefeller Foundation, at the Johns Hopkins School of Hygiene and Public Health, and received the M.P.H. degree. A war-time transfer to the Institute of Inter-American Affairs took him to El Salvador in 1942-43 as chief of party of the Health and Sanitation Division, and subsequently he was transferred to Mexico in the same capacity. In May 1946 he returned to TVA as Chief of the Malaria Control Division.

His bibliography contains more than 60 titles dealing with ecology of mosquitoes, malaria control, various arthropods and parasites of medical importance, tropical medicine and public health. He is a fellow of the Royal Society of Tropical Medicine, American Public Health Association, Entomological Society of America, American Medical Association, and the American Association for the Advancement of Science, and he is a member of the National Malaria Society, American Society of Tropical Medicine, American Academy of Tropical Medicine, American Society of Parasitologists, Academy of Medicine of Mexico, Mexican Society of Public Health, U. S.-Mexican Border Public Health Association, Academy of Natural History of Mexico, Society of Experimental Biology and Medicine, Alabama Academy of Science, Alabama Medical Association, Southeastern Biologists, American Mosquito Control Association, Liberian Institute of the American Foundation for Tropical Medicine, Societe Pathologie Exotique, Sigma Xi, and Phi Kappa Phi.

In 1946 the President of Mexico awarded him the Eduardo Liceaga Medal for distinguished contribution to Public Health in Mexico. Recently he was elected a member of the Interim Committee for the Fifth Congress of Tropical Medicine and Malaria.

EFFECTS OF ROUTINE DDT MOSQUITO LARVICIDING ON WILDLIFE

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Preliminary tests with DDT as a larvicide for the control of *Anopheles quadrimaculatus* mosquitoes demonstrated that this insecticide was toxic to fish and other forms of aquatic life. The Public Health Service, therefore, deemed it advisable to determine the over-all effects of the routine larvicidal use of DDT before it was recommended for widespread malaria control programs. The problem was to determine the effects on wildlife of the routine use of various methods of application and dosages of DDT and to determine at what dosage, if any, and in what manner or physical state DDT could be routinely used as an anopheline larvicide without being significantly harmful to other organisms of economic or recreational value.

PROCEDURES

Extensive investigations on this problem were begun early in 1945 and have been continued to date in close cooperation with studies on the value of DDT as an anopheline larvicide. During the first year investigations were made on the effects of routine hand application of DDT dusts, emulsions, and solutions. Preliminary studies were made on a large number of ponds and intensive investigations were carried out on 22 ponds, using several methods of application, types of larvicidal preparations and dosages of DDT to determine their joint and individual effects on fish and the surface, bottom and plankton organisms. DDT dusts were applied by means of rotary hand dusters at rates of 0.1 to 0.2 pound of DDT per acre. Air pressure hand sprayers were used for the application of emulsions and solutions which were applied at rates of $\frac{1}{2}$ or 1 gallon per acre and at dosages of 0.025 pound to 2 pounds of DDT per acre. Applications were made routinely at weekly intervals. Observations for the detection of gross kill were made on check and treated ponds just before application and 24 and/or 48 hours thereafter. Quantitative square foot samples of the surface organisms were taken at selected stations in all ponds prior to treatment. Paired samples were taken at these stations before and 48 hours after the first and second treatments and subsequently before and after alternate treatments. All sampling stations were selected in the richest areas of the ponds to assure the securing of all types of organisms in sufficient numbers to be dealt with statistically. Over 2200 quantitative square foot surface samples were taken in connection with the hand larviciding studies. All organisms were classified and counted and the resulting data analyzed statistically for the determination of t and P values.

Bottom samples were taken with an Eckman dredge at designated stations prior to treatment and at intervals during treatment. The mud was immediately washed from the bottom samples so the organisms could be picked while alive from the re-

maining debris and preserved in formalin for identification and enumeration. Over 1000 quantitative bottom samples were taken during the first season. Quantitative plankton samples were taken periodically from several of the ponds throughout the period of the study.

Prior to treatment, all ponds were seined to determine the fishes present and their relative abundance. Weekly observations were made of fish kills after each treatment and at the end of the season the fish population was determined by poisoning.

During 1946, the second season, studies were carried on at the Savannah River Migratory Waterfowl Refuge in cooperation with the U. S. Fish & Wildlife Service. From May to September some 815 acres in or around four ponds were treated weekly by means of an airplane at a dosage of 0.1 pound of DDT per acre. Two of the ponds were sprayed with a DDT *Velsicol NR 70*¹ solution while two received an exhaust Venturi aerosol of the same material. Two check areas were set up in an 800 acre pond about a mile distant from the treated areas. During the second year, all aquatic studies were continued and the investigations were expanded to include reptiles, birds, mammals, and terrestrial insects.

The sprayed ponds received 16 and 17 treatments respectively, while those treated with thermal aerosol received 15 applications. In each of the six study areas (two check and four treated areas), 100 quantitative square foot surface samples and 40 bottom samples were taken at designated sampling stations previous to treatment, during treatment, and at the end of treatment. This provided 1800 surface and 720 bottom samples for the determination of changes due to routine airplane larviciding with DDT. Fish population studies were made in each pond by enclosing an area of one acre with a barrier seine; the fish were poisoned, collected, identified, and weighed so qualitative or quantitative changes in the fish population could be determined.

Observations were made on snakes and turtles, and several were tagged to obtain data on movement and mortality. A weekly census of singing male birds and sight records of birds were begun in March and continued until August 8 for the purpose of determining trends of population on treated and check areas and for the mapping of the territories of the various pairs so mortality or changes could be detected. Live trapping and tagging of rats and mice were carried on previous to treatment and during treatment to determine mortality and trend of populations in treated and check areas. Daily sight observations were made on cottontail rabbits, cotton rats, and racoons on sprayed and unsprayed areas. Weekly light trap catches were made in check and treated areas before and after each treatment to detect any gross kill or trends in the insect population of the respective areas. Observations were also made on several hives of bees in the sprayed area.

During the third season the extent of the studies was drastically reduced. Observations were made on fish and insect kills and fish population studies were made to determine the effects of two years of routine airplane treatments with 0.1 pound of DDT per acre.

¹ A methylated naphthalene produced by Velsicol Corp., Chicago.

RESULTS

Effects of Hand Applications

Fishes. DDT emulsions applied at dosages of 0.2 pound per acre or more gave significant fish kills in small ponds after individual treatments. Oil solutions applied at rates of more than 0.4 pound of DDT per acre also gave fish kills after single treatments. At dosages of 1 to 2 pounds per acre, one treatment was sufficient to produce serious kills. It therefore became apparent early in the study that tight emulsions and solutions applied at a rate of 0.4 pound or more of DDT per acre were detrimental to fish in shallow ponds. Such methods and rates of application were therefore abandoned in favor of dusts or solutions applied at the rate of 0.1, 0.05 or 0.025 pound of DDT per acre. Individual treatments at these dosages caused no observed fish mortality. Routine treatments with dust at 0.1 to 0.2 pound per acre caused no significant fish kill; however, treatments at the same rate in oil solutions produced kills between the third and tenth treatments. A series of 11 to 22 treatments at 0.1 pound per acre seriously reduced the fish population in practically all the small ponds studied. Treatments with oil solutions at 0.05 pound of DDT per acre killed fish after the third treatment in one small sand-bottom pond, but in general, the first kills were noted between the tenth and thirteenth treatments. A series of 13 to 18 such treatments significantly reduced the fish population in small shallow ponds. No fish kills were observed after routine treatments of 0.025 pound per acre, but this dosage gives erratic control of anopheline larvae.

Tests were made with several other insecticides. Chlorinated camphene was found to be a very potent fish poison ranking with rotenone in this respect. Oil solutions of DDT at 0.1 pound per acre killed significant numbers of fish, but at dosages of 0.05 pound per acre it appeared to be less toxic than DDT. Similar results were obtained with chlordane. It was found, however, that the type of pond greatly influenced the toxic action of DDT. One heavily vegetated pond which received 14 routine treatments at 0.1 pound of DDT per acre had no observed fish kill while another deeper pond having no rooted aquatics and receiving the same number of treatments at 0.05 pound per acre had a significant kill. In general, however, treatments of 0.1 pound per acre gave much more rapid and pronounced kills than 0.05 pound per acre.

Insects. The large surface insects such as Corixidae, Noto-nectidae, Gerridae, Belostomatidae, Dytiscidae, Hydrophilidae, Gryinidae, Haliplidae, and Naucoridae were killed by all dosages of DDT tested (Tarzwell 1947). However, kills at 0.1 pound per acre were much greater than those secured with dosages of 0.05 pound or less. Dust treatments killed only small numbers of surface insects even at 0.1 and 0.2 pound per acre. The larger dosages in oil solution probably killed 90 per cent of the large surface insects during the first two treatments; however, in no instance were these forms eliminated and a few were present after even 22 treatments (Tarzwell 1947).

Paired quantitative square foot surface samples indicated few significant changes in surface organisms due to individual treatments at dosages of 0.025 to 0.1 pound

per acre (Tarzwell 1947). With routine treatments throughout a season, however, some significant changes occurred. In general, these changes were more pronounced for the larger dosages of DDT solutions. Nematodes, Oligochaetes, and Copepods generally increased in numbers while insects, especially the Diptera, Coleoptera Hemiptera, and Ephemeroptera, decreased in numbers. Other forms remained largely unchanged. In general, the increase in Nematodes and Oligochaetes was so great that there was a great increase in the total number of surface organisms in the ponds most affected by the DDT.

Plankton. Factors other than the treatment such as temperature, wind force and direction, diurnal phasic activities of the organisms, sunlight, degree of oxidation or putrefaction of the organic content and seasonal trends produced changes in the plankton population which were much greater than those demonstrated for individual treatments. Further, there did not appear to be a significant seasonal change attributable to the DDT treatments as pointed out by Bishop (1947). It is concluded that plankton is a poor indicator for demonstrating effects of DDT on the aquatic environments.

Effects of Airplane Treatments

Mammals. Because malaria control involves the use of small routine application of DDT, studies of the effects of larviciding on mammals were made over the season as a whole (Erickson 1947). From May 1 to September 6, 52 cotton rats were taken in 2449 trap nights on 14 acres of unsprayed area while on 16.7 acres of sprayed areas, 106 cotton rats were trapped in 2428 trap nights. Eleven (21.1 per cent) of the rats trapped in unsprayed areas were retaken while 27 (25.4 per cent) of those taken in sprayed areas were recaptured. These results indicate the the activity of the rats and the rate of mortality were about the same in both areas. Twenty-one immature and 31 adult cotton rats were trapped in the unsprayed area and 50 immature and 54 adults in the sprayed area indicating that DDT had no apparent effect on the reproductive potential of the rats in the sprayed area.

Sight observations on cottontail rabbits, cotton rats, and racoons made throughout the season while driving 168 miles in the unsprayed and 256 miles in the sprayed area showed no significant difference in the abundance, reproduction, or activity of these animals in the two areas.

Birds. The census of singing male birds and sight records in sprayed and unsprayed areas before the first treatment and over the whole period of study revealed similar population trends in both areas (Erickson 1947). The number of singing male birds in both sprayed and unsprayed areas showed an increase during treatment caused apparently by the arrival of late migrants. The spraying of DDT had no apparent effect on the males that had been singing in March, April, and May, for their singing continued until July and August. The slight variation that occurred in the distribution and numbers of singing males in each area during the summer were similar. The absence of a sudden drop or a gradual decline in the population of the treated areas indicates that routine spraying did not affect the bird population to any appreciable extent.

Terrestrial Insects. During the period of treatment, routine observations in both

check and treated areas showed only those differences in general insect numbers and activity which could be considered due to differences in the respective ecological situations. No over-all effect was observed, but field observations on mosquitoes, deer flies, and sand flies in the treated areas indicated a reduction in their population, whereas the check area showed high population of these insects. Aside from these insects, no other gross effects were noticeable, for grasshoppers, ants, dragonflies, damselflies, wasps, bees, and other common forms appeared in usual abundance.

Six light traps, two in check areas and four in treated areas, were operated the night before and the night after each DDT treatment. One hundred individual trap collections from these six traps averaged 1043 insects per night.

This is a fairly uniform mean, but occasionally the catch varied to a great extent due to the weather or heavy emergence flights of mayflies and staphylinid beetles. The Coleoptera, Lepidoptera, Diptera, and Trichoptera composed the bulk of the collections in the relative order of abundance as named. The trap catches showed a good degree of correlation with each other and showed no drastic reductions due to treatment. Reductions appeared to be most pronounced among the Diptera. Gross observations made within 8 hours after spraying demonstrated that the insects most commonly found dead or dying were mayflies, damselflies, *Donacia*, longlegged flies and miscellaneous acalyptrate muscid flies.

Five ten-frame hives of Italian honey bees were kept under observation in the sprayed area and were subjected to 17 DDT treatments having an average surface deposit of 0.03 pound per acre per treatment. The bees showed no abnormalities in their activities which could be assigned to DDT. Each colony produced several extracting frame supers, and the owner stated that the colonies had had a very successful year regardless of the DDT treatments.

Reptiles and Amphibians. Tagging and observations of turtles failed to demonstrate any kills due to treatments. A few dead snakes were found, and it is apparent that they are susceptible to DDT poisoning in areas of heavy treatment or where there is a high concentration of DDT due to wind action or other causes. They are apparently affected both by contact and by the poisoned fishes they may eat. Several dead frogs were found after treatment, but no general or catastrophic kills of frogs or their tadpoles were noted. The sirens appeared to be quite resistant to DDT, as they were found in considerable numbers in all ponds at the end of treatment.

Fishes. Intensive observations and counts were made of dead fish and insects in all ponds 24 to 36 hours after each treatment. Some dead fish, mostly gizzard shad and sunfishes, were found throughout the course of the treatments. There were no catastrophic kills at any time during the first two years of treatment during which the sprayed ponds received an average total surface deposit of about 2 pounds of DDT per acre and the aerosoled ponds about 0.4 pound of DDT per acre.

Fish population studies made in sample areas of one acre before treatment and at the end of each year of treatment demonstrated no harmful results to the fish population. In each pond, each population study was made in the same areas so results would be directly comparable.

Surface Organisms. Changes in the population of surface organisms in the ponds

treated by airplane were not as regular or marked as those occurring in the ponds receiving hand treatment. This is probably due to a more uniform and smaller average dosage. There were indications of some increase in the Nematodes and Oligochaetes in the treated ponds, but increases among the Copepods and Gastropods were not uniform. Decreases in Amphipods, Isopods, and *Palaemonetes* were marked and regular denoting that these Crustacea are very sensitive to DDT. There were also indications of some decreases in the Coleoptera, Hemiptera, and Chironomids. Changes in the Ephemeroptera were not consistent and with the exception of the Crustacea noted above no decreases were of much significance. Changes in the ponds receiving the aerosol were not as marked as those occurring in the ponds which were sprayed.

CONCLUSION

Hand Applications of DDT in Small Ponds

As a dust, routine applications of DDT caused little apparent damage to surface organisms. Paired square foot surface samples taken before and 48 hours after treatment indicated few significant changes due to single treatments. The seasonal trend of the population of surface organisms was somewhat affected by routine treatments with dust at the rate of 0.1 pound of DDT per acre, but changes were not as great as those caused by treatments with solutions of DDT in fuel oil. DDT-fuel-oil solutions killed the large surface insects at concentrations as low as 0.025 pound of DDT per acre. Kills resulting from applications of 0.05 or 0.025 pound of DDT per acre were proportionately much less than those resulting from treatments at the rate of 0.1 pound per acre. The seasonal effects of routine DDT treatments were quite marked. There was an increase in the numbers of Nematodes, Oligochaetes, Copepods, and Gastropods and a decrease in the Chironomids, Hemiptera, Coleoptera, and Ephemeroptera. The net result of these changes are perhaps a reduction in the total food supply available to the fish. Reductions noted to date, however, have not been sufficient to affect the breeding stock, and since treatment is in localized areas, it is probably not sufficient to seriously limit the fish population by restriction of the food supply.

As used for the control of malaria vectors, the detrimental influences of DDT upon the plankton population of small water areas is so slight in comparison with natural variation due to climate and other ecological factors that it is unimportant in upsetting the biological balance. No catastrophic kill of any specific group of organisms occurred.

DDT dusts can be applied routinely at dosages of 0.1 pound per acre with little or no significant harm to wildlife.

Tight emulsions of DDT are more toxic to wildlife than DDT fuel oil solutions

Routine treatments with fuel oil DDT solutions at dosages of 0.1 pound per acre generally kill large numbers of fish after the tenth treatment and with continued use greatly reduce the population of fish and fish food organisms.

Routine treatments with solutions at dosages of 0.05 pound of DDT per acre usu-

ally result in fish kills between the tenth and thirteenth treatments and with continued use will drastically reduce the fish and fish food populations in small water areas where the entire water surface is treated.

No fish kills were noted following routine treatments of 0.025 pound of DDT per acre, but this dosage has proved inadequate for satisfactory mosquito control. For adequate mosquito control, dusts or DDT oil solutions at dosages of 0.1 pound and 0.05 pound per acre respectively are recommended. Even though some kills occur, at these dosages, the total harmful effects on wildlife will be slight due to the limited extent of the areas treated and the short period of treatment. Further, areas which are treated by hand are usually due to their intermittent nature and shallow water, of only slight value for fish production and recreational use.

Airplane Application of DDT Larvicides

Routine treatments at discharge rates of 0.1 pound of DDT per acre had no observed significant effects on the reptile and amphibian populations.

The natural driftage of DDT sprays and aerosols from water areas onto surrounding terrestrial areas had no detected harmful effects on bird and mammal populations during one season's treatments. Further, no catastrophic or significant general changes were produced in the terrestrial insect populations.

Such treatments did not impair the strength of bee hives located on adjoining areas or decrease their production of honey.

Routine treatments at discharge rates of 0.1 pound of DDT per acre as sprays or aerosols do not significantly change the populations of surface insects during one season's treatment. Oligochaetes and Nematodes increase somewhat, and Amphipods, Isopods, and *Palaemonetes* are drastically reduced; but these latter usually constitute such a small portion of the total population that the biological balance is not adversely affected.

Although routine airplane treatments over a period of two years produced some fish kill chiefly among the gizzard shad, minnows, and sunfish family, the total fish population was not changed and production in pounds per acre remained about constant.

Routine airplane larviciding at discharge rates of 0.1 pound of DDT per acre is not significantly harmful to wildlife of economic or recreational value at least during the first two years of treatment.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to his associates and other members of the staff who have assisted in the wildlife studies. He is especially indebted to his co-workers engaged in various phases of the study, namely: Dr. A. B. Erickson on birds and mammals; Dr. E. L. Bishop on plankton; and Mr. Harvey Scudder on terrestrial insects. Much credit is due Mr. William Lynn, Mrs. Dorothy Coleman, Mrs. B. B. Whitmarsh, Mrs. Rosetta Edwards and Mr. Joe Gillespie for carrying on much of the tremendous quantity of detailed work required for the collection, counting and tabulating of the surface and bottom samples.

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A NEW SPECIES OF PROTOZOA MET WITH IN THE SALIVARY
GLANDS OF *A. culicifacies*, GILES, IN THE COURSE OF
ROUTINE MALARIA SURVEY—*Trypanosoma kalwanensis*
VISWANATHAN AND BHATT (1948)

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INTRODUCTORY

One of the squads of the Bombay Provincial Malaria Organisation has been engaged in carrying out a malaria survey in Kalvan and Dindori talukas of Nasik District (N. Lat. 20.5° and E. Long. 74.2°) in South India since September 1947. It was a part of the instruction in all surveys that permanent preparations should be made of gland and gut infections of *plasmodia* met with in the anophelines for confirmatory examination by the senior author. The junior author recognised the occurrence of uncommon forms of parasites in a dissection of salivary glands of *A. culicifacies*, Giles, on 3-11-1947. The gut was not examined as the worker was rapidly on the move and wished to dissect as many glands as possible in order to incriminate the local vector species for malaria before the anticipated end of the season of transmission by the end of December. The mosquito was collected on 2-11-1947 from a cattleshed in Kalvan, a taluka headquarter station, population a little over 4000, and spleen rate a little over 10 per cent. As the uncommon parasite described hereafter was seen by the senior author only four months later, further immediate local investigations have not been possible. But no unusual mortality had been reported among men, animals, rodents or birds.

Flagellates in salivary glands of A. culicifacies

The slide was dried, fixed and stained with Giemsa's on 3-11-1947 when the junior author found plasmodial sporozoites in the fresh preparation of the salivary glands. When all similar preparations were being examined for confirmation by the senior author the following forms of parasites were met with in the slide under reference:—Uninucleate sporozoites, some of which showed a second reddish stained mass at one end, leishmanial, leptomonad, crithidial and trypanosome stages of flagellates some of which were devoid of flagellae; One or two cells containing a 'plasmodia' of leishmania; One pear-shaped flagellate with two nuclei and two flagellae, presumably a multiplying form and conglomerating metacyclic trypanosomes. The attached diagram shows the various forms met with.

MORPHOLOGY

The flagellate is pleomorphic, not only all phases of development from the leishmanial to trypanosome stages being met with but the crithidial and trypanosome stages consisting of the 'small slender', the 'stumpy' as well as 'intermediate' forms.

While most parasites have flagellae a few forms without flagellae are also seen. The small, slender flagellates are about 9 microns (body) and 7 microns (flagellum) and are narrow. The stumpy and intermediate forms vary from 9 to 12.5 microns (body)

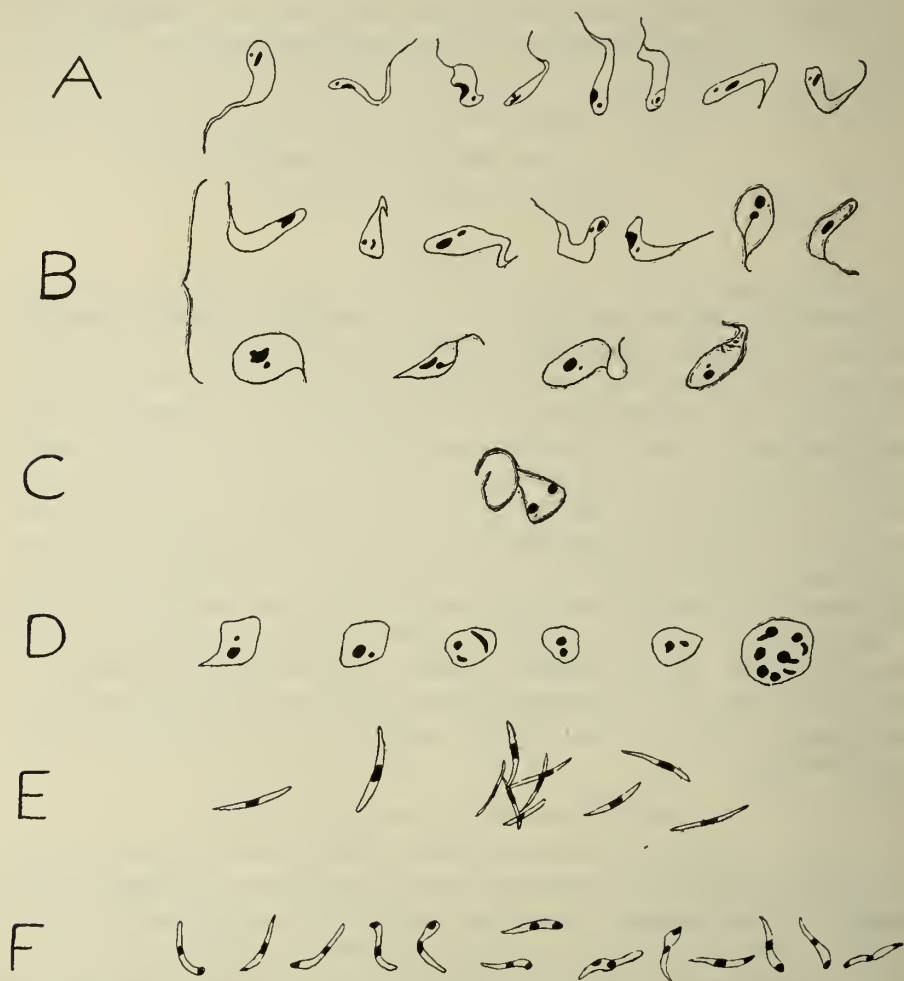


FIG. 1. *Trypanasoma kalwanensis*

- A.—Trypanasome—slender, stumpy and intermediate forms.
 B.—crithidial forms. -DO-
 C.—dividing form with two nuclei and two flagellae.—
 D.—Lishmanial forms.
 E.—Plasmodial sporozoites.
 F.—Sporozoites with second chromatoid dot at one end.

and about 4 to 5.3 microns (flagellum). Occasional rounded forms about 7 microns in diameter with a flagellum about 5.3 microns in length are also seen. The 'sporozoite' forms are mostly about 9 microns long. A few are shorter still. These forms

have all a distinct central nucleus. A large number have besides another reddish compact dot mostly at one pole but in a few cases nearer to the nucleus. The sporozoites are not all typically pointed at both ends. In most cases one end is blunt. A couple of cells contain multiple leishmania forms grouped like plasmodial merozoites, the cell itself about 10 microns in diameter. The single multiplying form met with was about 8 microns by 4 microns (body) with divided nucleus and flagellum the latter about 3.6 microns long.

DISCUSSION

Leaving aside the uninucleate 'sporozoites' for later consideration, the flagellate shows development in all stages including the trypanosome. Hence it belongs to the genus *Trypanosome* if an additional vertebrate host is postulated, *Phytomonas* if a second plant host is assumed and *Herpetomonas* if the mosquito is deemed to be the only host. A further possibility is that the flagellate may have been a contaminant of the distilled water used in the stain or may be the intestinal flagellate of the domestic fly which may have smeared its faeces on to the slide. Distilled water may be ruled out since the same bottle has been used as a routine in the laboratory and no flagellates have been seen in any other slide. The occurrence of all phases of development, the preponderance of trypanosome stage, the presence of metacyclic forms and the absence of encysted forms together with relatively smaller size of the parasite and its flagellum all rule out contamination of the slide with trypanosomes from the faeces of the domestic fly.

It is not likely that the flagellate has only a single invertebrate host, the anopheles mosquito. In the first place the insect flagellates are transmitted from host to host through encysted forms in the faeces with the solitary exception of *Crithidia hyalomae* in the host *Hyalomma aegyptium* which apparently only sucks blood and in which infection is likely to be transmitted to the offspring through the ovary though it has not yet been demonstrated. In the present case, the presence of all phases of development in the salivary glands in large numbers rules out the possibility of invasion into the tissues of intestinal forms from the gut, although it has to be admitted that the chloroforming of the insect prior to dissection may have reduced the resistance of the gut wall and facilitated invasion of gut forms into the tissues. On the whole however this does seem likely since even metacyclic forms which do not occur in the intestinal flagellate have been encountered. While several flagellates have been described in the mosquitoes both anopheles and culex, with very few exceptions, they have all been found in the alimentary tract. Mathis (1914 quoted by Wenyon, 1926) found a flagellate of *Crithidia* type in the salivary glands of a species of *Culex* in Tonkin: Development forms in the body cavity and salivary glands of *L. culicis* have also been described. Wenyon (1926) refers to the possibility that such flagellates in tick and mosquito may have been derived from vertebrate trypanosomes.

Not only have typical conglomerating metacyclic forms been met with, but there are quite a few discrete forms which are without flagellae. These latter may either be haptomonad forms whose attachment to cells has been loosened by pressure on the cover slip or they may also be post-flagellate infective or metacyclic forms.

As regards *Phytomonas* the blood sucking habits of the insect rule out a plant

host. It is true that the mosquito was fed on raisins for one night, but these raisins have been examined and found to be free from any flagellates.

On the whole, therefore, the flagellate is considered to belong to the genus *Trypanosoma* with the vertebrate host still undetermined. The procedure regarding nomenclature in *Trypanosomes* is confusing. They are named after the host to avoid confusion though not in accordance with strict rules. In the present cases the vertebrate host is undetermined and it is surmised that the invertebrate host is not the only host, the genus thus being *Trypanosoma*. The authors wish to call it *T. kalwanensis*, Viswanathan and Bhatt, (1948), after the place of its collection.

There now remains the presence of uninucleate 'Sporozoites', some of which have a second reddish dot mostly at one end (vide illustration) to be discussed. The uninucleate 'Sporozoites' if they were alone present will certainly be assumed to be plasmodial sporozoites. As they were not more than 9 microns in length they are probably avian in origin. In a couple of fields a tendency to clumping of these sporozoites was also seen which is generally more common in avian plasmodial sporozoites. On the other hand such clumping sporozoites has been noticed in the same area in another specimen in which the sporozoites were slightly longer, about 10 to 12 microns, but not nearly as long as human plasmodial sporozoites generally are. In a tract which is hyperendemic for malaria, sporozoites in salivary glands of the anophelines mosquito are generally assumed to be of human origin. Whatever the origin of the uninucleate sporozoites they may be deemed to belong to the genus *Plasmodium*. Some of them have a second reddish dot and they are blunt at one end and pointed at the other. Is the second dot granular, does it represent the kinetoplast of the flagellate or is it a second nucleus? There could be no further elucidation from the single stained specimen. Plasmodial sporozoites do not generally have a second red staining dot, (with Romanowski's stain) and hence such forms may be taken to represent a preflagellate phase of development of the flagellate parasite. On the other hand uninucleate forms of flagellates are not recognised and no flagellates have been described without a kinetoplast. Neither the nuclear origin of the kinetoplast nor the fusion of the two is specifically accepted. Schaudinn's observation or rather deduction of development of *T. noctuae* in *Culex pipiens* is not accepted, nor is his account of the development of *Haemoproteus noctuae* in *Culex pipiens*, postulating a trypanasoma stage in the vertebrate host, syngamy in the mosquito stomach and liberation of spirochaete like bodies, confirmed. Wenyon (loc. cit.) refers to further generalisation made by Hartmann and others, based on Schaudinn's views, that all pigmented blood parasites are closely related to trypanasomes which are supposed to possess two nuclei. According to Wenyon these authors appear to have homologised the reddish staining granules of parasites with the kinetoplast. In the present case if all the phases are assumed to relate to one parasite there is some further evidence in partial support of the concept of some of these authors, not for the view that *Mastigophora* are binucleate but for a uninucleate sporozoite phase of development of the trypanasome or *per contra* a trypanasome phase of the uninucleate haemosporidia. A single stained specimen cannot obviously carry one any further and hence we believe in conformity with the accepted views that the uninucleate sporozoites are plasmodia probably of birds, that the sporozoites having a second reddish mass may

be either plasmodia in which case the mass is probably granular or they represent a phase of development of the flagellate which is found in large numbers in other stages of development with typical nucleus, kinetoplast and flagellum. One may only hope for further elucidation in the lucky event of a second specimen of the parasite being met with during the further conduct of the survey which will last till March 1949.

SUMMARY

A new species of protozoa, *Trypanasoma kalwanensis*, Viswanathan and Bhatt, (1948) met with in the salivary glands of *A. culicifacies* in South India is described.

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INFLUENCE OF THE MOON ON LIGHT TRAP COLLECTIONS OF *ANOPHELES ALBIMANUS* IN PUERTO RICO

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(Received for publication 24 June 1948)

During World War II, the Malaria Control in War Areas Program of the U. S. Public Health Service made surveys or operated projects in twenty areas in Puerto Rico and Jamaica. At the height of the program, collections were being made at least once a week from about 100 animal bait traps and every night from about 20 light traps, in order to establish indices to adult population of *Anopheles albimanus* Wiedemann mosquitoes. In summarizing the entomological data each month for these projects, it became evident that the indices established by animal bait and light traps were not entirely comparable. Both the bait trap catches and the light trap collections fluctuated more or less on a seasonal basis. However, the light trap collections exhibited cyclic fluctuations within each month which could not be explained solely on the basis of mosquito production. A succession of large and small light trap catches, although of different magnitude in each trap, occurred almost simultaneously over the entire area regardless of rainfall, irrigation, or other conditions. It is the purpose of this paper to discuss this cyclic fluctuation in the size of the light trap collections as related to the "bright" and "dark" phases of the lunar month. Unpublished entomological data from three M.C.W.A. projects are presented herein together with data from papers dealing with five other military bases (Henderson 1945 and Weathersbee 1946). The locations of all of these projects are shown on Fig. 1.

The animal bait traps were small metal, wooden, or thatched traps approximately five and one-half feet wide, eight feet long, by five and one-half feet high, into which calves or small horses could be driven and kept overnight to serve as bait for mosquitoes. The mosquitoes entered the traps through the V-shaped openings and were collected the following morning with aspirators from the upper screened portion of these traps. Light trap collections also were used to provide an additional index of adult mosquito populations. Certain other data are also presented concerning animal bait and light trap collections based on four years' work with light traps and bait traps throughout Puerto Rico.

In Puerto Rico, *Anopheles albimanus* breeds continuously the year round and noticeable changes in numbers are usually associated with the varying sizes of breeding areas. This species is maintained at a relatively low and constant population during the dry season which extends from December or January through late March, April or May. There is one peak in numbers at the beginning of the rainy season in May and June and a gradual rise to peak populations at the height of the rainy season, usually in October, November, or early December. The brood phenomenon which gives peaks in mosquito populations at intervals of three to six weeks with

anophelines in the United States, or after periods of heavy rainfall with salt marsh mosquitoes, apparently is not as pronounced with *albimanus* populations in Puerto Rico.

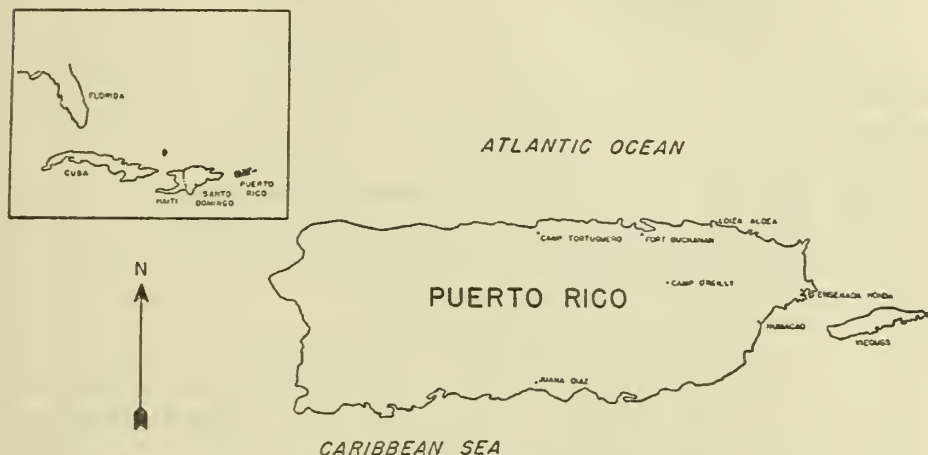


FIG. 1. Location of MCWA Projects in Puerto Rico

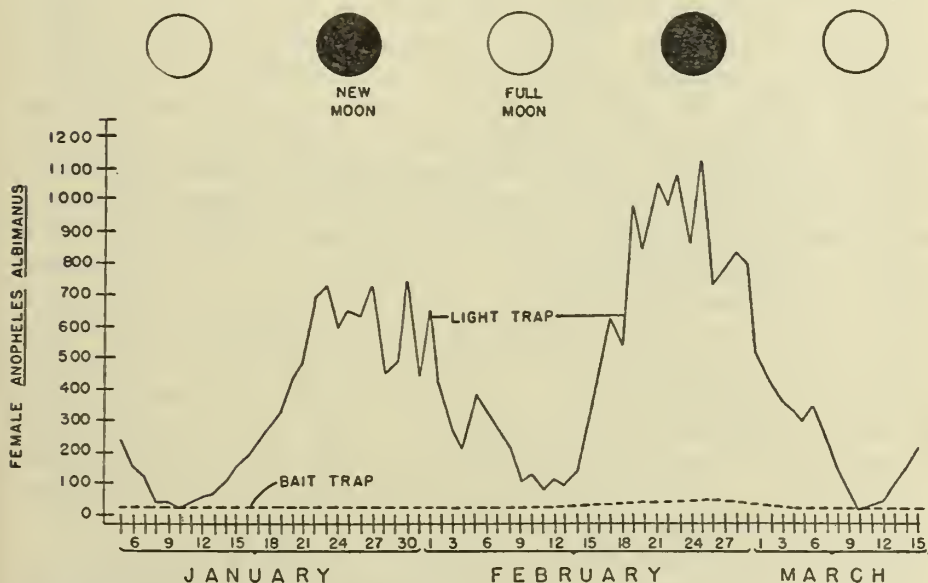


FIG. 2. Influence of Lunar Cycle on collections of *Anopheles albimanus* in Light Trap No. 4 at Losey Field at Juana Diaz, Puerto Rico.

During the dry season from January through March 1944 both light traps and bait traps were operated at Losey Field in Juana Diaz on the south coast of Puerto Rico. The bait trap collections indicated a relatively low and constant population of from 5 to 25 *albimanus* per night while the catches in one light trap (No. 4) showed variations of from 10 to 1100 (Fig. 2). Collections made during the "bright phase"

of the lunar cycle, which includes two to five nights before and after full moon were uniformly low as during the period January 7 through 14, February 9 through 15, and March 8 through 12, 1944. Then, as the moon decreased in size and was in the sky for an hour less each night, collections rose rapidly and reached maximum size during the "dark phase" of the lunar cycles. This dark phase usually lasts for three to five nights before and after the new moon, as during the period January 21 through February 1 and February 19 through 29. Finally, as the moon increased in size and was in the sky for an hour longer each night, collections dropped sharply and were lowest during the following "bright phase" of the lunar cycle.

Anopheles albimanus has a flight range of at least two miles in Puerto Rico. Therefore, animal bait and light traps were placed in a two mile zone around war establishments to help determine those areas producing the most anophelines and to give an index to the degree of control obtained in the various zones. Data from one line of three light traps at Juana Diaz are presented in Fig. 3. One trap was located on the Army Post, one a mile east of the Post and one two miles east of the Post. Data for these traps have been graphed using the average daily collection of *albimanus* by calendar weeks from Saturday to Saturday beginning in September 1945 and ending in February 1946. This method has the advantage of showing in a single chart the trend in collections over a long period of time as well as giving smoother curves due to the ironing out of minor rises and falls on individual nights. Usually the points are averages of seven catches per week, but occasionally these are averages of only four to six collections due to the light bulb burning out or a time switch not operating. It is at once apparent that the catches of female and male *albimanus* in the light traps increased many fold going from the center of the control zone outward. Light Trap No. 1 on the Base in the center of the control zone had average catches of 0 to 10 female *albimanus* per night and no male *albimanus*. Light Trap No. 2 halfway between the Base and the edge of the control zone had considerably higher collections ranging from averages of 3 to 60 female, and 0 to 6 male, *albimanus* per night. Collections in Light Trap No. 4 on the edge of the two mile control zone had counts with averages of 32 to 188 female, and 3 to 57 male, *albimanus* per night. The graphs of the collections in all three traps show essentially the same five peaks and valleys. Collections in all three traps increased as the moon decreased in size and reached their peaks either during the week of new moon or second quarter. Then, as the moon increased in size, the bright moonlight offered more competition for the light trap. The mosquitoes perceived the light less clearly and were attracted in smaller numbers during the periods of full moon to last quarter.

This relationship between the lunar phases and the cyclic rises and falls in the size of light trap collections is a continuous process as is shown in the graphs in Fig. 4. This chart shows the collections of male and female *albimanus* in Light Trap No. 4 in Juana Diaz during 1945. As in Fig. 3, the data used in preparing this graph are average, daily catches for the calendar weeks Saturday to Saturday, without regard to lunar months. There is a peak in collections about the time of the new moon, or the "dark phase" of each lunar cycle, and a marked drop in size of collections near or soon after full moon in the "bright phase" of the lunar cycle. Similar rises and falls in the numbers of *albimanus* taken by this trap occurred in 1943, 1944 and 1946. These data are not presented here.

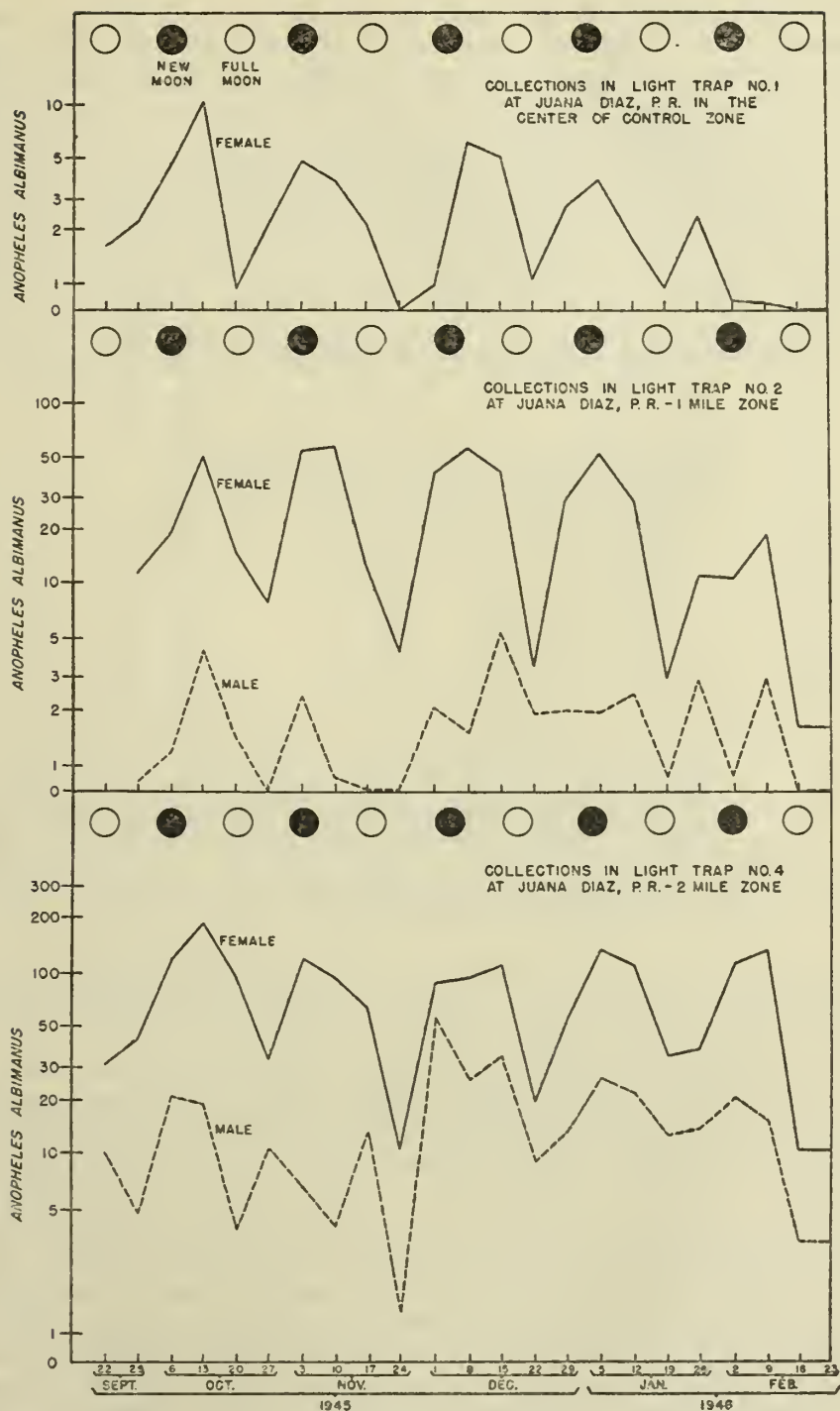


FIG. 3. Comparison of collections in control zone, one-mile zone, two-mile zone in relation to the lunar cycle.

Further information on this phenomenon is shown by light trap collections at widely separated locations throughout Puerto Rico. Fig. 5 presents graphs of average daily collections of *albimanus* in light Trap No. 1 at Humacao Playa on the east coast of Puerto Rico, in Light Trap No. 2 at Loiza Aldea on the north coast of Puerto Rico some 25 miles away, and in Light Trap No. 4 at Juana Diaz on the south coast of Puerto Rico some 50 miles away. In the period from November 1944 through March 1945 the general trend in *albimanus* populations is somewhat different at each project because of the different size and character of breeding areas at each of the three locations. Each graph, however, shows five pronounced peaks and valleys rather definitely correlated with the "dark" and "bright" phases of the five lunar months.

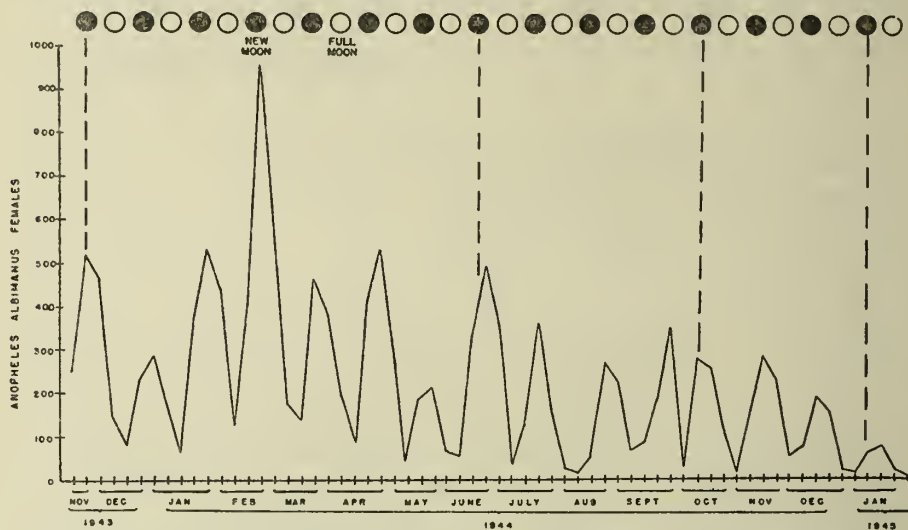


FIG. 4. Influence of Moon Phases on *Anopheles albimanus* behavior as shown in average daily collection in a light trap at Amelia—two miles east of Losey Field, P. R.

It is quite evident that the moon is exerting a powerful influence on the size of light trap collections simultaneously at all three projects which are separated from one another by high mountain ranges and considerable distances.

In evaluating the data from light and bait trap collections of *Anopheles albimanus*, it appears that the bait trap may give a truer conception of the actual trends in anopheline population although it frequently collects fewer mosquitoes than does the light trap. Fig. 6 shows a good comparison of light trap versus animal bait trap collections at Juana Diaz. Bait Trap No. 4 which was operated once a week had relatively low counts with no noticeable rises and falls until October 28 when a large collection of 80 *albimanus* was caught. On the other hand, Light Trap No. 1 which was operated every night had sizeable catches with regular fluctuations on an approximately four week cycle for the five months August through December. It will be noted that the light trap collected many more *albimanus* than did the nearby animal bait trap except when the moon was in the "bright phase." Full moons occurred on August 4, September 2, October 3, October 31, and November 30, 1944. The

failure of the light trap to catch more *albimanus* than the nearby bait trap—as is apparent in Fig. 6 on September 3, October 28 and the period November 24 through December 3—was due to the brilliant moonlight.

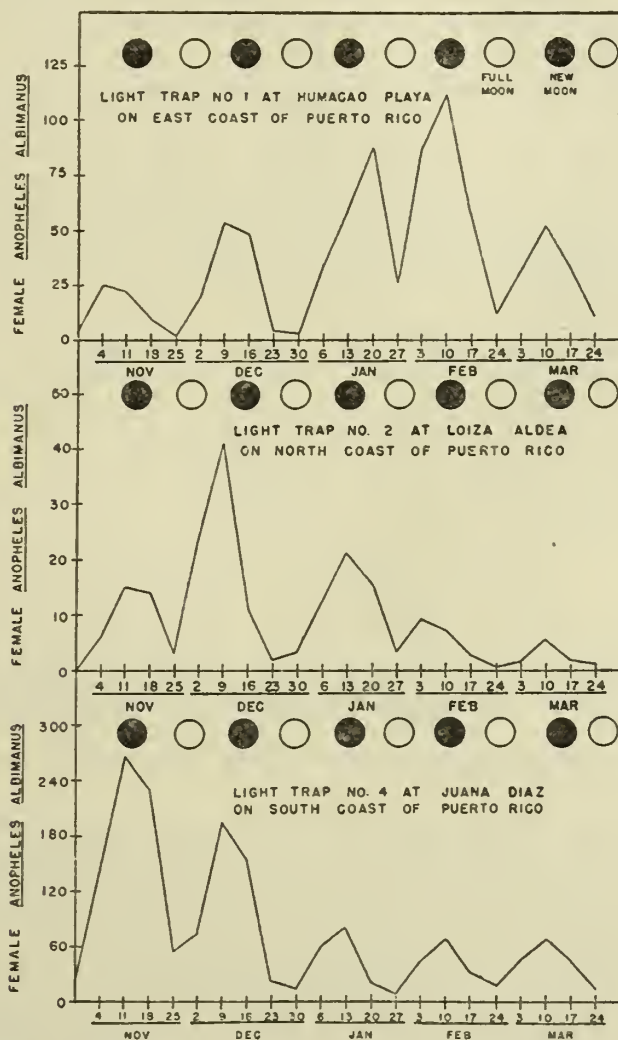


FIG. 5. Comparison of the influence of the Lunar Cycle on trap collections at widely separated locations.

Several studies have been made with regard to the level to which the population of *Anopheles albimanus* must be lowered in order to reduce malaria morbidity to a minimum, what might be termed "an aiming point for satisfactory control."

Earle (1937) showed that there was no great reduction in the number of cases of malaria in Salinas among a civilian population living in unscreened houses until mosquito collections averaged less than one *albimanus* per trap per night.

On a military base this index may be assumed to be somewhat higher, because of better anti-adult measures, such as the use of residual DDT spraying, the screening of all buildings, the general availability of bed nets, and the more wide-spread use of repellents and adulticides such as freon-pyrethrum bombs. Henderson (1945) has shown that the majority of cases of malaria *presumed to be contracted* on U. S. Army posts in Puerto Rico during the years 1942–1944 occurred at times when average, overnight animal bait trap collections on the cantonment zone contained five or more *albimanus* at three posts (Fort Buchanan, Camp Tortuguero, Camp O'Reilly) and two or more *albimanus* at one post (Losey Field). Similarly, Weathersbee's (1946) data show that most of the cases of malaria occurring on the two U. S. Navy Bases at Ensenada Honda and Vieques in the eastern part of Puerto Rico in 1941, 1942 and 1943 occurred when animal bait traps on these Bases contained five or more *albimanus* per trap per night.

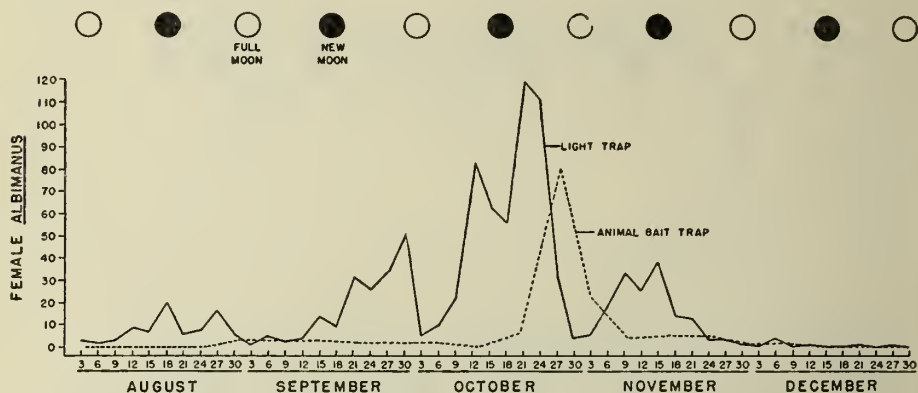


FIG. 6. Comparison of *Anopheles albimanus* collections in light trap and in bait trap at Losey Field in Juana Diaz, P. R.

It would therefore seem that the aiming point for "satisfactory control" of malarial mosquitoes in Puerto Rico would be about one *albimanus* per average overnight collection *in bait traps* in the central zone in civilian areas, and average catches of two to five *albimanus* per trap per night on military posts.

As will be appreciated from the preceeding discussion of data on light trap collections, the determination of an index for "satisfactory control" *based on light trap collections is more difficult* due to the cyclic fluctuation in the size of such collections as a result of the influence of the moon. However, it may be stated that in general, little or no malaria transmission occurred when catches on the military posts averaged 1 to 5 *albimanus* per overnight light trap collection during the "bright phase" of the moon and as high as 5 to 20 per overnight collection during the "dark phase" of the moon. It is definitely known that on two posts malaria case rates of 50 to 200 per 1,000 per annum occurred when average, overnight, light trap catches of 20 to 40 *albimanus* or more occurred on military bases for several weeks or months.

These indices, or aiming points, for "satisfactory control" of *Anopheles albimanus*

are naturally tentative. In the United States during World War II the Malaria Control in War Areas Program and the U. S. Army attempted to set up similar indices as to "satisfactory control." If an adult collecting station had 10 or more *Anopheles quadrimaculatus* per catch for three or more weeks in a row, that area was considered to have unsatisfactory control. From light trap collections of *Anopheles quadrimaculatus* on U. S. Army Posts, King and Kuhns (1943) have written that "an average of two or three specimens per night now is regarded as approaching an undesirable density level."

DISCUSSION AND SUMMARY

Bradley and McNeel (1935) studied mosquito populations at Zellwood, Florida in 1932 and wrote that "a bright moon over any considerable period . . . appeared to be unfavorable (to large mosquito catches), the trap accumulating the largest numbers on still, dark nights." Horsfall (1943) has shown that collections of *Anopheles quadrimaculatus*, the principal vector of malaria in the eastern United States, "even though their source is fairly uniform, are attracted to light traps in varying numbers as changes occur in the lunar cycle. When the moon is full or nearly so, the numbers attracted to light ebb; and when the moon is new they are attracted in greatest numbers. The light trap is more or less effective in proportion to the intensity of the light from the moon. The darker the night, the greater the area over which the trap light exerts its attractiveness, and consequently the greater the numbers of mosquitoes attracted, other things being equal."

Anopheles albimanus, the principal vector of malaria in Puerto Rico, shows essentially the same diphasic curve with peak collections during the "dark phase" and lowest collections during the "bright phase" of the lunar cycle. When an animal trap is operated near a light trap, the light trap collections are often higher than those in the bait trap during the "dark phase" of the lunar cycle, and approximately equal to, or lower than, those in the nearby animal bait trap during the "bright phase" of the lunar cycle. In a previous article (Pratt, 1944) it was shown that when three light traps with 25-, 50-, and 100-watt bulbs located about 150 feet from each other were operated simultaneously, the traps attracted *albimanus* in numbers which were approximately proportional to the wattage of the three bulbs. The numbers of *albimanus* collected in light traps, therefore, seems to vary with the relative intensity of the light given out by the light trap—whether due to the wattage of the bulb employed in the trap (Pratt 1944) or due to the relative illumination given out by a bulb of fixed wattage competing with moonlight whose intensity fluctuates cyclically every four weeks.

This phenomenon may be explained by a very simple theory, namely, that during the "bright phase" of the lunar cycle, the mosquitoes do not see the light trap as well as during the "dark phase," and consequently are attracted to the light trap in smaller numbers near full moon than they are near new moon.

Data are presented indicating that an index of 1 to 5 *albimanus* per light trap per night during the "bright phase," and 5 to 20 *albimanus* during the "dark phase," of the lunar cycle may be comparable to the index of 2 to 5 *albimanus* per bait trap used as an "aiming point of satisfactory control" on military bases.

ACKNOWLEDGMENTS

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AIRPLANE DISTRIBUTION OF INSECTICIDES AND HERBICIDES FOR MALARIA CONTROL

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The use of airplanes for distributing insecticides and herbicides in certain phases of malaria control operations has been shown to have a number of advantages over other methods of applying these chemical materials. Included among these advantages are fewer numbers of personnel, rapid area coverage, ease of operations, particularly in poorly accessible areas, small amount of equipment, timeliness of application, and economical operation. For example, ground applications which are employed in connection with larviciding include boat and shoreline crews for spraying and shoreline maintenance, and the equipment required consists of knapsack sprayers, axes, saws, and bush-hooks as well as vehicles to transport men to proper areas. With the exception of certain phases of shoreline maintenance it is possible for one pilot and one airplane to carry out effectively larvicidal operations which would require a large number of ground units. It is estimated that four foremen and twenty-four men on ground operations require two weeks to cover areas which can be treated by one airplane and pilot in eight hours flying time.

The utility and economy of airplane larviciding may be appreciated from the fact that only five airplanes are scheduled to handle all work on TVA reservoirs during 1949. The operations will embrace treatment in fifteen reservoirs extending a distance of 750 miles from the upper reaches of the Tennessee River to its convergence with the Ohio River. A total of 440 flying hours is expected to be required in applying DDT larvicide to some 50,700 cumulative treatment acres over a period of 20 weeks during the mosquito season. This figures about 115 treatment acres per hour which includes non-treatment flying time as well as ferrying between reservoirs and bases of operation. A total of 6,050 gallons of 20%-DDT Velsicol larvicide or 11,300 pounds straight DDT will be used. The normal dosage is 0.1 lb. DDT per acre of mosquito breeding area, but due to variations in size and shape a high degree of wastage or overage treatment occurs ranging between 60% and 100% in the different reservoirs. It is estimated that a comparable ground treatment operation would cost at least 3 or 4 times the airplane operations anticipated. For various reasons the ground operation would not be as effective or as dependable as the airplane operation, particularly in emergency situations.

With a background of over ten years of airplane application for control of anopheline larvae in the Tennessee Valley Authority (Watson et al., 1938, and Kiker et al., 1938), it seems desirable at this time to present some of the detailed information that has been obtained in connection with aircraft requirements and equipment as well as the factors which need careful consideration in the selection and training of a pilot for such operations.

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AIRPLANE TYPE

Although the selection of the best airplane type for dispensing a dust, aerosol, or spray is a very important consideration, we find that no airplane has been built to meet all the requirements of an "ideal" special work airplane. Cost, sturdiness, and load capacity have often been given much consideration in the choice of an airplane, whereas a number of other factors should be taken into account. Although airplane applications for control of insects have been going on for over a quarter of a century (see complete bibliography, Hawes and Eisenberg, 1947, Stage and Irons, 1947, and Popham, 1946), the extent of the work has not been sufficient to initiate production of a plane designed expressly for the purpose of insect or plant control operations.

Factors involved in the selection of the type of airplane include:

1. Load capacity—weight and bulk of equipment and material
2. Airplane characteristics
 - a. Dependability
 - b. Speed range (working and ferrying)
 - c. Range in miles
 - d. Maneuverability
 - e. Ease of handling
 - f. Visibility
 - h. Safety
 - i. Downdraft
3. Economy
 - a. Initial cost
 - b. Maintenance costs (service and repair parts, including availability)
 - c. Operational costs

In evaluating the various factors listed it must be realized that certain ones will assume greater or lesser importance, depending on the specific job to be done. For example, no consideration is being given to large aircraft such as C-47's and B-25's which have been used successfully in military mosquito control work. When such planes are considered for larvicidal operations in the Tennessee Valley, it can be readily seen that they would be ruled out on the economy factors as well as on size, maneuverability, and ease of handling. On the other hand, there are certain requirements which are more important in malaria control work than for agricultural crop dusting. Many breeding areas for *Anopheles quadrimaculatus* are surrounded or bordered by trees of varying heights. For efficient airplane application of insecticides or herbicides the plane must be very maneuverable with sufficient power to pull up sharply, be easy to handle, have good visibility and downdraft, and not be too large to get into the breeding areas. These characteristics are much more important in anopheline larvicidal control work than in insecticide applications over a cotton or corn field.

The Tennessee Valley Authority has had an excellent opportunity to compare the Boeing-Stearman Model 4D with the Consolidated Vultee BT-13, both being equipped with 450 h.p. Pratt and Whitney engines. The Stearman biplane is slower (see table 1) and capable of very sharp pull-ups and quick maneuvering turns. It also has good load-carrying capacity for the engine horsepower. Visibility is poor in this plane, however, and, since it is a fabric covered plane, it offers a greater fire

hazard. The plane has high maintenance costs due to the inaccessibility of the various engine and airplane components and the necessity of replacing the fabric covering

TABLE 1

A list of some of the available small to medium single-motored airplanes which are being used or could be used for insecticide-herbicide applications and important considerations concerning their use.

PLANE TYPE	HORSE-POWER	SPEED* RANGE	APPROXIMATE LOAD CAPACITY WORKING MATERIAL	FLYING CHARACTERISTICS		COSTS		
				Safety	Range	Initial	Operating	Maintenance
			<i>pounds</i>		<i>miles</i>			
Aeronca (L-3)- (7AC)	65	60-75 75-80	250	Fabric	200	Low	Low	Low
Fairchild PT-19	175	80-100 100-105	400	Fabric Wood	300	Low	Moderate	Moderate
Fairchild PT-23	220	80-100 105-110	450	Fabric Wood	300	Low	Moderate	Moderate
Boeing-Stearman 4-D	450	80-105 115	1,400	Fabric	450	Unavailable	High	High
Boeing-Stearman PT-17	220	75-85 90-100	500	Fabric	300	Low	Moderate	Moderate
Navy N-3-N	235	75-85 90-100	500	Fabric	300	Low (War Sur- plus)	Moderate	Moderate
Piper Cub (L-4)- (J-3)	65	60-75 75-80	250	Fabric	200	Low	Low	Low
Piper Supercruiser	100	80-95 100	350	Fabric	300	High	Low	Low
Stinson (L-5)	190	80-105 115-120	400	Fabric	350	High	Moderate	Moderate
Taylorcraft (L-2)	65	65-85 85-90	250	Fabric	200	Low	Low	Low
Vultee BT-13	450	90-120 135-140	900	Metal	600	Low	High	Moderate
Waco	220	75-90 90-100	500	Fabric	300	(War Sur- plus) Low	Moderate	Moderate

* First figures indicate approximate working speeds, second set ferrying speeds in m.p.h.

which has a rather short life. If distance is an important consideration, the plane is at a disadvantage because its ferrying speed is only about 115 mph. Considerable

effort is also required to fly this plane. The Vultee monoplane, on the other hand, is easily handled, comfortable for the pilot, and provides excellent visibility. Its maintenance cost is lower due to all-metal construction and the easily removed side panels and inspection holes which make component parts of the aircraft and engine quite accessible. The all-metal construction also diminishes the fire hazard. The speed range for working (90–120 mph) and ferrying (135–140 mph) is also greater. The plane has a little greater effective downdraft, but this factor is not as noticeable as with lighter Cub planes, which, over forested areas, may have insufficient downdraft to force a dust down to the breeding areas (Stage and Irons, 1947).

There are some disadvantages to the Vultee monoplane that should be considered when selecting an airplane for conversion to a dust, spray, or aerosol work ship. The wing span, 43 feet, is rather wide for some areas, which thus requires these areas to be flown at a higher altitude. The location of the wing in regard to the pilot's position makes judgment of distances at wing tip rather difficult. This airplane has a faster landing speed and requires a longer landing roll than most other small and medium airplanes and would not be as safe in event of forced landings. The installation of a dust hopper would be more expensive and would require more engineering changes in the airframe.

TYPES OF EQUIPMENT

The important feature regarding equipment installation on airplanes is that any such modification must meet all requirements of the Civil Aeronautics Administration. One should be completely familiar with their regulations and requirements before installing parts or altering structures on the plane.

In general, the alterations must not diminish the airworthiness of the airplane. Equipment for dusting, spraying, or application of thermal aerosols must be well constructed and must not weaken structures of the airplane. No fire hazard may be created by any of the equipment. The use of electric-driven pumps is permissible only when vapor-proof motors are employed. Whenever a wind-driven pump is used, its location must not present a hazard to pilot or airplane, nor can it interfere with the flying characteristics of the airplane. Equipment and dust or spray material must not alter the normal center of gravity limits as determined by the Civil Aeronautics Administration for empty and loaded conditions.

Dust application. Installation of a dust hopper is governed by two different considerations, proper construction for the load carrying and release of the material and unimpairment of the plane's efficiency, safety, and balance. Diagrams of airplane dusting equipment are available for several types of planes (see p. 199 in Krusé, Hess and Metcalf, 1944, also Anonymous, 1945, and Husman, 1943).

The important features to be considered in the carrying and release of the dust include:

1. Adequate slope of side walls of hopper (an angle of 130° has proved satisfactory).
2. Venturi location and shape. (See Figure 1.)
 - a. For wide calibration range to include various dosages and materials.
 - b. To assist in pulling dust from hopper.
 - c. To insure uniform discharge.

3. Agitator location (in hopper just above narrow throat).
 - a. To prevent packing.
 - b. To maintain continuous flow of dust when valve door is open.
4. Leakproof.

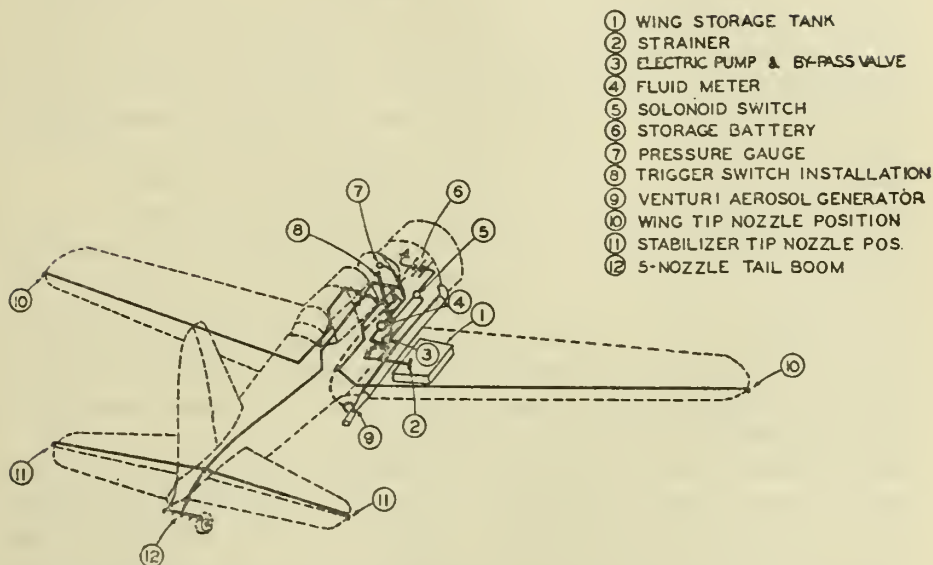


FIG. 1. Schematic drawing of Vultee BT-13 airplane equipped for applying 2,4-D herbicides and DDT larvicides as sprays or thermal aerosols.

Certain other characteristics must be considered in the design and installation to insure efficient, safe operation:

1. Inflammability hazard (due to inflammable dusts, e.g., sulfur).
 - a. Shields for loading and proper location of exhaust outlets.
 - b. Release mechanism with non-sparking parts.
2. Bulkheads aft of cockpit.
 - a. To protect pilot from dust particles.
 - b. To prevent weight shift of dust to rear of fuselage involving unbalancing craft.
3. Venturi design and installation must not cause an appreciable drag on airplane and consequent diminution of speed and climbing characteristics.

Spray and thermal aerosol application. The insecticide or herbicide is commonly prepared as an oil solution or emulsion for dispersal as either a spray or thermal aerosol so that the tank, pipe lines, strainers, pressure regulator, and pressure gauge may be common for both types of application. The maximum permissible tank capacity must be determined in relation to total liquid weight both for adherence to Civil Aeronautics Administration regulations and for adequate tank strength. The tank must be readily accessible for filling, draining, and cleaning. A readily cleaned strainer should be located between the tank and pump.

Tank. The tank capacity is largely governed by liquid weight. Total weight must meet Civil Aeronautics Administration requirements and will govern the strength of its construction. The tank must be well baffled, securely mounted, and

properly located to insure pilot safety in case of a serious leak. The tank must be readily accessible for filling, draining, and cleaning.

Strainer. The strainer should be located between tank and pump to prevent any clogging. It should be removable for easy cleaning.

Pumping unit. The pump may be wind-driven (Krusé and Metcalf, 1946) or an electric pump which operates at constant speed. The electric pump should be vapor-proof with sufficient capacity for aerosol or spray application (a pressure range of 10 to 100 pounds per square inch has proved satisfactory). The electric pump is used in conjunction with a trigger grip electric solenoid switch on the pilot's control stick. This gives the pilot a free hand for throttle operation if necessary.

Pressure regulator and gauge. An adjustment should be accessible to the pilot in flight, particularly if aerosol and spray equipment is installed on the same airplane. A single pressure gauge for either type of application should be located where it may be easily read.

Control valves. Control valves should be installed for regulating the flow of liquid to the aerosol or spray unit. When separate spray outlets are used on wing tips and tail assemblies, it is convenient to have separate valves. For shoreline spraying it would be advantageous to have a cut-off for each wing spray.

Spray equipment for control of *A. quadrimaculatus* may differ somewhat from that used for crop application. In general, it appears that sufficient spray nozzles or outlets for mosquito larviciding can be installed at various points about the wing tips and stabilizer tips. Changeable nozzles should be employed to control quantity of material, particle size, and swath width. A check valve should be mounted at each nozzle to minimize dribbling. The pump and tubing capacity must be chosen with regard for the desired maximum output of either spray or aerosol equipment.

Aerosol equipment has been described by Krusé and Metcalf (1946). It is sufficient to state that the diameter of the exhaust stack extension or pipe is determined by the horsepower, cubic inch displacement, temperature, and back pressure. The length of the stack extension is dependent upon Civil Aeronautics Administration regulations pertaining to back pressure and temperature. The particle size of the liquid droplets is dependent upon the venturi design, nozzles used, velocity, and temperature of exhaust gases and liquid flow into venturi. The pressure regulator and nozzle size determine this flow. A spring loaded check valve near the nozzles in the venturi is desirable to give a clean cut-off as with sprays. The operating rpm and manifold pressure of the engine also affect the particle size. Thus a constant rpm is desirable. It may be obtained by using a propeller governor with a fixed power setting for dispensing material.

PILOT SELECTION

Careful selection is necessary when obtaining a pilot for airplane dust, spray, or aerosol application used for mosquito or plant control work in a malaria control program. It is suggested that a pilot selected for the work with no previous dusting experience should be within the 21 to 28 year age group and have good reactions and physical qualifications that would enable him to stand long and irregular hours which might be required for timely insect control. His schedule for a single day might

include an early morning dusting (dawn and shortly after), possibly servicing his own airplane, field inspection trips, checking maps and larval dipping reports, and consulting with his supervisor regarding dust applications to be made the following morning. Sometimes a late afternoon dusting followed by airplane servicing is necessary during the same day. The applicant's previous flying record, including hours, types of aircraft flown, and types of flying done must be carefully considered. His even temperament, interest and conscientious effort in his work, and pride in caring for and maintaining his plane in best condition are all important attributes for a prospective pilot in this type of work.

TRAINING THE PILOT

The training program should be well planned and executed by an experienced pilot familiar with the type of work and areas to be treated by the new pilot.

Familiarity with the type of airplane is the first important step. This is accomplished by about two hours ground cockpit time in which the location of all instruments and controls is learned, including dusting, spraying, or aerosol equipment, flow meters, timing devices, etc. Upon completion the ship should be flown (without a dust or spray load) for approximately five hours at a safe altitude. The pilot should practice stalls, sharp pull-ups, reversal of direction, steep turns, and other dusting maneuvers outlined by the experienced dusting pilot. Following this practice period the ship should be loaded about two-thirds full capacity and three hours spent on the same maneuvers, followed by two hours of maneuvers with plane fully loaded.

The first efforts at low altitude work should be done with an empty airplane, spending at least five hours on this type practice, all the while being observed by the instructor who at his discretion should put enough material in the airplane during the latter part of this phase of the training to allow the trainee to open and close the valve controlling the release of the material. This should also provide the pilot with practice in placing the material and judging swath width. All of the above training should be done over open areas free of obstructions.

The next training should include ground reconnaissance over areas similar to routine areas fairly free of obstructions followed by two flights over this area with the instructor at the controls showing the trainee how he would approach the area and the direction to make his turns in the open part of the area adjoining the area to be treated. The trainee should spend approximately five hours treating such areas, noting the accuracy of his efforts to place the material on certain parts of the area designated for treatment. No new areas should be worked until the pilot (either new or old) has made a ground reconnaissance trip over the area either by car, boat, or walking, noting all obstructions and width of flight areas between trees or obstructions. When flying the area he should approach and circle over the area for the first time at a safe altitude. Many ground reconnaissance trips over areas to be treated during the first two seasons of work and much time spent with ground personnel, such as supervisors, larvae and adult inspectors, pay off in making an all-round good treatment pilot. When making such trips the pilot should receive enough entomological and botanical information to understand thoroughly where breeding locations may be expected. His knowledge of the typical breeding areas will prevent

unnecessary applications in certain areas and provide reason for multiple applications in breeding areas where flying is difficult. Herbicide work is similar to insecticide work as treated areas are usually the same and the material is distributed in the same manner except that a larger amount of material may be used.

The new pilot should be checked on the consistency of his height of flight on various areas and practice holding a constant altitude and airspeed to best suit the calibration, swath width, droplet size, drift, and placing the material where it is needed.

Weather conditions play an important part in the distribution of insecticides and herbicides by airplane. Calm air conditions must prevail and the temperature should not be too high for the most effective placement of the materials on areas to be treated. The requirements of calm air conditions necessitate early morning or early evening flying. Visibility must always be good enough for a safe flight over treatment areas which have any obstructions. Ceilings, however, need only be high enough to meet the minimum requirements of the Civil Aeronautics Administration as dusting, spraying, or aerosoling operations would not require a ceiling as high as that set forth by the C.A.A. for commercial flying. The pilot should study the trends of the weather for the locality in which he works so as to take advantage of the best conditions.

Topographic conditions must be studied by the pilot and he must be able to orientate himself readily in getting from area to area and in cross-country flights, taking advantage of the best hours and weather for the work. The height of hills and terrain adjoining dusting areas will determine the direction he will make his swaths since a level or low area must be utilized for safe pull-ups and turns.

Flight reports are needed for various types of airplane treatment in connection with malaria control work. The basic information required to be reported on TVA routine operations covers date, pilot, airplane number, air base, reservoir, flight number, type treatment, name of chemical, pounds of active chemical, gallons of chemical solution, hours flying time designating the amount for ferrying, acres actual breeding area treated, specific graphic designation of treatment areas, and budget account number (see fig. 2). A space for remarks is provided for recording any desirable additional information such as heights of flight, weather conditions, etc. Flow meters installed on the solution discharge lines as well as the use of automatic or manually operated stop watches facilitate calibration of spray equipment, checking on flow, treatment rates, and measuring amount of solution applied to specific areas. All this information is very helpful and needed by the engineer and biologist in summarizing the needs for work and in making improvements in treatment or design of equipment. Similar reports are highly desirable for any airplane application of chemicals.

SUMMARY

Airplane application of chemicals has been used extensively in the malaria control program of the Tennessee Valley Authority for more than ten years. The experience gained in these operations has made possible an evaluation of airplane types, dust, spray, and thermal aerosol equipment for use on airplanes, and important factors which need consideration in selection and training of pilots for such work.

The factors which are involved in airplane selection have been presented and evalu-

FIG. 2

TVA-1596 (RPD-448)

DAILY FLIGHT RECORD

MALARIA CONTROL AIRPLANE OPERATIONS

TENNESSEE VALLEY AUTHORITY

Reservoir..... Pilot..... Date.....

Airplane No..... Airfield..... Flight Report No.....

FLIGHT NO.	TYPE OF WORK*	EXTENT OF TREATMENT ACRES	NAME OF CHEMICAL APPLIED	LBS. OF ACTIVE CHEMICAL APPLIED	GALLONS OF SOLUTION APPLIED	TIME OF FLIGHT		DURATION OF FLIGHT	
						Begin	End	Hrs.	Min.

Totals

	LOCATION OF FLIGHT OR TREATMENT (RESERVOIR SHORELINE MILE DESIGNATION)	CHARGE ACCOUNT NUMBER

* Designate work as: (1) DDT Aerosoling, (2) DDT Spraying, (3) 2,4-D Herbiciding, (4) General Reconnaissance, (5) Testing Equipment, (6) Spotting Growth, (7) Aerial Photography, (8) Transportation, (9) Ferrying, (10) Other.

Remarks:.....

Original—Transportation Accounting Office

1 copy—RPD Area Office

1 copy—Chief Airplane Pilot

1 copy—Reservoir Sanitary Engineer

1 copy—Retained by Pilot

ated for several types of planes. Broadly, they include load capacity, flying characteristics of the plane plus safety, visibility, size, and economy.

A discussion is presented of the types of equipment which may be installed and the accompanying requirements which are governed to a great extent by the Civil Aeronautics Administration. The qualifications which are desirable in the selection of a new pilot are presented and a recommended training program is outlined.

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NEW PLANS FOR VECTOR CONTROL IN CALIFORNIA

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The year 1947 marked the beginning of a new period of vector control in California. On July 1st of that year the State Department of Public Health established the Bureau of Vector Control to study and control arthropods of medical importance. This new bureau consolidated within the Division of Environmental Sanitation the work of mosquito control and rodent survey previously done by other departmental units.

Since 1916, the department had conducted an active program in rodent survey work. In recent years this activity was primarily in field plague surveys and in collaboration with epidemiologists in field studies of plague, anthrax, rabies, psittacosis and typhus.

In 1946, the department was given the responsibility for the administration of a \$400,000 subvention fund for local mosquito abatement work, for studies and demonstrations, and for emergency action in case of mosquito-borne disease outbreaks.

Wilton L. Halverson, M.D., State Director of Public Health, indicated the Department's interest in this field in his address to the California Mosquito Control Association in December, 1946. He stated, "Our interest has been stimulated by wartime experiences and today we are more than ever impressed with the importance of arthropods as vectors of disease and recognize that the control of these arthropods is a science fundamental to the field of Public Health and preventive medicine."

ANALYSIS OF VECTOR-BORNE DISEASES IN CALIFORNIA

Vector-borne diseases in California were critically reviewed and nine vector diseases having the highest potential in California as of July, 1947 were analyzed as a basis for planning vector control activities. These diseases are encephalitis, fly-borne diseases, malaria, plague, Q-fever, relapsing fever, rocky mountain spotted fever, tularemia, typhus fever. The results of this analysis were tabulated on a chart, Figure 1, entitled "Analysis of Vector-Borne Diseases in California." The diseases are listed alphabetically since their relative order of importance may change at any time.

Each disease was considered with respect to: (1) problem in the State, (2) the past and future programs in the State, and (3) needed research.

An arbitrary A-B-C scale was used to indicate comparative values on points considered in evaluating the problem and past program for each disease with "A" representing a high value, "B" moderate, and "C" a low value.

The "problem" was analyzed as to: incidence in humans and animals; vector knowledge and prevalence; and reservoir knowledge and prevalence.

The State Health and Safety Code does not limit the Department's responsibility to diseases of man, but includes domestic animals—therefore, horses are considered, as in the case of Equine Encephalomyelitis.

Inspection of the evaluation of the disease "Problem" reveals that encephalitis and murine typhus are at present the most important vector-borne diseases. In addition, there are many unknowns and weak points in our knowledge of the "funda-

DISEASE	PROBLEM						PROGRAM												RESEARCH			REMARKS
	Incidence		Vector		Reser- voir		Endemic survey				Cont. demonstration				Control program				Etiol. agent	Reservoir	Vector	
							Past		Future		Past		Future		Past		Future					
	Human	Animal	F.F.	Prev	F.F.	Prev	Res	Vec	Res	Vec	Res	Vec	Res	Vec	Res	Vec	Res	Vec				
Encephalitis.....	Act. A Pot. A	A A	B Inc	A	?	?	C	B	=	<	A		=	B*	A	=	=	+	+	+	*Horse vaccination and mosquito control	
Fly-borne diseases ..	Act. ? Pot. A ?	? ?	A A	A	A	A	O	O		<				<								
Malaria.....	Act. C Pot. C		A	A	A	?	O	C*		=	A		=		A		=				*Incidental to encephalitis program	
Plague.....	Act. C Pot. C		A	A	A	A	A	A	>	>	C	O	<	<	B	O	<	<	+	+	*Seasonal carryover	
Q. Fever....	Act. C Pot. C	?	?	?	?	?	O	O	<	<												
Relapsing fever.....	Act. C Pot. B		A*	C	?	C	C	C	<	<	O	O	<	<	C**	O	<	<	+	+	*Study circumstances of infection **Department of Agriculture *Limited to three counties: Modoc, Siskiyou, Lassen Even water involved (Muskrat)	
Rocky Mountain Spotted Fever*....	Act. C Pot. ?		A	?	?	?	O	O	=	<												
Tularemia...	Act. C Pot. B	C C	A Inc.	A	B Inc.	B	A	A	>	>												
Typhus Fever.....	Act. A Pot. A		A Inc.	A	B Inc.	B	C	C	<	<	C	O	<	<	C	O	<	<	+	+	Case density high	

Symbols. > = Decrease, < = Increase, = = No Change, Act. = Actual, Pot. = Potential, F. F. = Available Fundamental Fact Knowledge; Prev. = Prevalence, Arbitrary Intensity Scale: A = High, B = Moderate, C = Low, O = None, Res. = Reservoir, Vec. = Vector

FIG. 1. ANALYSIS OF VECTOR-BORNE DISEASES IN CALIFORNIA—JULY, 1947

mental facts," and the "prevalence" of vectors and reservoirs. To obtain the needed "fundamental facts" research must be stimulated.

The past State program has been evaluated according to the three basic phases of activities carried out in any vector control program, namely endemic surveys, control demonstrations, and control programs. Both the reservoir and the vector must be considered in each case. These activities have been projected into

"Analysis of Vector-Borne Diseases in California," as the "past program" activities. Inspection of the past program reveals certain pertinent facts:

1) More emphasis has been placed on endemic surveys than on control demonstrations or control programs.

2) The greatest amount of endemic survey work has been on the reservoirs and vectors of plague and tularemia.

3) The major emphasis of control demonstrations and control programs has been on the mosquito vectors of encephalitis and malaria.

4) Minimal emphasis of control demonstrations and control programs has been on the rodent reservoirs of plague, typhus and relapsing fever.

5) On several of the nine diseases listed, no work or very little has been done with respect to endemic surveys, control demonstrations or control programs.

When this review of what had been done in the State was complete, it was possible to indicate where more or less work should be done in the future using the evaluated "problem" as a guide. As an illustration of how Figure 2 works, let us follow the analysis of encephalitis through the evaluations of the "problem," "program" and "research."

1) *Incidence*: The actual and potential incidence of encephalitis in man and equine encephalomyelitis in animal was evaluated. A large number of cases occur each year and potentially a great number more could occur. Therefore, encephalitis was considered to be one of the most important vector diseases in California. The highest rating "A" was assigned for both humans and animals.

2) *Vector*: Our knowledge of "fundamental facts" on the vector is moderately good, but incomplete, for the circumstances of infection are not known. These facts were rated as "B." To obtain this information further research is needed on vectors as indicated. Accepting mosquitoes as the vector, the rating of their prevalence is "A."

3) *Reservoir*: With respect to the reservoir of encephalitis, we cannot insert an entry for we have no definite knowledge on the real reservoir. Accordingly, further research has been indicated for "reservoirs." Continued research is being done on the etiological agent.

4) *Endemic Surveys*: With respect to endemic surveys of encephalitis, work on "reservoirs" in the past has included some collection of arthropods in the field and testing in the virus laboratory to locate the reservoirs, and was therefore given a "C" rating. Considerable effort has been expended on determining the incidence of mosquito species and the rate of natural infection. Vector endemic surveys are therefore given a "B" rating. In the future, it is proposed that a minimal effort be continued on endemic survey for the reservoir, and a greater amount of work be done on the mosquito vector to determine statewide distribution and infection.

5) *Control Demonstrations*: A number of control demonstrations have been conducted on mosquito vectors in the past of an "A" magnitude. It is proposed that the same effort be continued in the future. No work is indicated for the "reservoir" due to lack of fundamental knowledge.

6) *Control Program*: The "reservoir control program" for encephalitis in the state, has been limited to horse vaccination by veterinarians which is assigned a "B" rating due to extent of vaccinations. This work will be continued. While the horse is not

generally considered a "reservoir" it is known to have a positive viremia during the disease. The "A" rating for "control" activities on the vector indicates the activities of local mosquito control organizations supported by state subvention assistance on well-balanced "programs" to the extent of \$400,000 a year. The future "vector control program" calls for a continuation of these activities.

All nine diseases were reviewed in the same manner as encephalitis. Indicated changes in emphasis of the three phases of the "future program" provide guidance for determining the activities which the Bureau of Vector Control should engage in. This plan of "program" development permits long range planning and continual re-evaluation.

BUREAU OF VECTOR CONTROL OPERATIONAL PLAN

Accepting the basic responsibilities of the sections of mosquito control and sanitary inspections, the Bureau of Vector Control developed a fundamental plan of operation expanded in accordance with the "Analysis of Vector-Borne Diseases in California."

This plan called for an advisory committee to guide the department in evaluating vector diseases and establishing policies and "programs." Such a vector control advisory committee was established with representation from the University of California, the G. W. Hooper Foundation for Medical Research, local health departments, and mosquito abatement districts.

The basic organization called for all activities to be considered as field activities under the direction of the chief of the bureau, supported by epidemiological activities of the department and office services of the bureau. The field activities fall logically into three major categories following the section on "program," of the "Analysis of Vector-Borne Diseases in California," namely, endemic surveys, studies and demonstrations, services and control programs.

Endemic surveys include all surveillance activities of the Bureau, of a continuing or intermittent nature. They include activities designed to permit continual evaluation of vector-borne diseases of actual or potential danger to the people of the state. These activities also include such surveillance activities as the U. S. Public Health Service, Communicable Disease Center Activities, is obligated to perform in California.

Studies and demonstrations are necessary to improve the work being done and to serve as a basis for our recommendations on such activities. The studies and demonstrations cannot be considered pure "research" for they involve the determination of operational variations of techniques and "programs" used elsewhere. For this reason they are generally referred to as "operational demonstrations."

Services and control programs within the Bureau of Vector Control include all direct operating activities which involve control of vectors either on the state or local level. These activities include: direct services in the case of outbreaks of vector-borne diseases; consultation and recommendations to local health departments, agencies and individuals engaged in related vector control work; and educational developments for the purpose of improving the quality of work of the bureau or local personnel engaged in the control of insect vectors.

BUREAU OF VECTOR CONTROL PERSONNEL

Having established the functional responsibilities of the bureau we can review its personnel and staff. This plan is of a long-range and continuing nature, and the personnel available must serve in more than one capacity. Certain studies will be carried on at different periods of the year to facilitate efficient use of personnel on a year-round basis. Besides the staff provided by the State of California, personnel are provided through the U. S. Public Health Service Communicable Disease Center Activities unit in California, which is assigned to the Bureau of Vector Control and forms an integral part of the bureau organization.

The present state program calls for a staff of 40 persons, including nine professional sanitary or public health engineers, and/or medical or public health entomologists, assisted by six sanitarians, six rodent control foremen, fifteen rodent control officers, a secretarial staff of four, besides funds for student research assistants on temporary employment. In addition, Communicable Disease Center Activities personnel in the state at present include the state entomologist, a field entomologist, an entomological inspector, besides the administrative assistant and a clerk-typist.

CONCLUSION

In conclusion we acknowledge that the Bureau of Vector Control has accepted a tremendous challenge in its "New Plans for Vector Control in California." This challenge includes responsibility to maintain a current analysis of the vector-borne diseases as well as to adjust endemic surveys, control demonstrations, and control programs to conform to our rapidly expanding knowledge of the vector-borne diseases in California.

BOOK REVIEWS

"Medical Writing, The Technic and Art." 2nd Ed. MORRIS FISHBEIN, M.D., Editor, The Journal of the American Medical Association with the assistance of JEWEL F. WHIELAN. 292 pages with 36 illustrations. The Blakiston Co., Philadelphia, Pa. 1948. \$4.00.

The material in this book has been developed as a result of handling thousands of manuscripts for the Journal of the American Medical Association and the various special periodicals published by the Association.

Valuable and important suggestions have been well integrated in this new edition and helpful new suggestions are presented in the chapter on Indexing by Miss Laura E. Moore and in the chapter on Illustrations by Mr. William Brown McNett.

The book will be of service to physicians and writers in all scientific fields preparing articles ranging from the briefest report to a full treatise. It offers help in formulating style, abbreviation, spelling and capitalization rules, proofreading, indexing as well as the essential knowledge needed to assure proper treatment of a scientific or medical subject and give expert guidance in the display of individuality and literary talent.

"Malaria Control on Impounded Water." By the Staff of the Division of Health and Safety of the Tennessee Valley Authority and the United States Public Health Service. Pp. xiii + 422 (Washington: Superintendent of Documents, U. S. Government Printing Office, 1947). \$2.00.

The southeastern United States had many costly experiences with "man-made" increases in malaria, during the second and third decades of this century, associated with the impoundage of flowing streams. Following these disastrous occurrences and litigation which resulted from certain of these epidemics of malaria, state health department regulations governing the conditions under which water might be impounded were adopted in many of the southern states. These regulations or state laws were based upon the basic studies of the United States Public Health Service which established clearly the fundamental relationships between impounded water and malaria and the steps necessary for its control.

The present manual is a cooperative effort between the malaria control staff of TVA and the United States Public Health Service. When the Tennessee Valley Authority in 1933 undertook its program of regional development based primarily on water control, a unique opportunity was provided for the study and application of alternative malaria control measures under circumstances eventually involving more than 10,000 miles of reservoir shoreline, in a region of widely varying topography. As stated in the foreword: "The experience of the United States Public Health Service has, of course, been acquired over a much broader geographic and ecologic range than has that of the Authority. Thus, there is here joined the experience gained by both intensive work on a regional basis and extensive operations on a national scale."

The preface states "The purpose of this manual is to present the basic principles and the modern practices of malaria control on impounded water. It is arranged so as to provide a ready reference for engineers, medical officers, and others concerned with malaria control measures on such impoundments. In considering the various phases of malaria control such as its epidemiological, engineering, and biological aspects, emphasis has been placed on their practical application to the problem as a whole."

Chapter headings include Malaria and Its Relation to Impounded Water, Planning Malaria Control, Reservoir Preparation, Permanent Marginal Measures (as for example, diking and dewatering and deepening and filling), Water Level Management, Shoreline Maintenance, Larviciding, Mosquito-Proofing, House-Spraying, Facilities and Operation Procedures, Malaria Mosquitoes, Malariology (epidemiology, surveys, etc.), The Relation of Plants to Mosquito Control, Interrelationships of Malaria Control and Wildlife Conservation, Personnel Training and Public Relations, and Small Reservoirs. Eight appendices include summaries of state laws and regulations pertaining to malaria control on impounded water, specifications on chemicals or equipment employed in malaria control, detailed data on anopheline mosquitoes, malaria survey diagnostic technique, etc.

Space does not permit an adequate review of the individual chapters, but it is the reviewer's opinion that the individual subjects have been treated in a very thorough and authoritative manner. This is to be expected on the basis of the brilliant contribution to the specialized problems associated with impounded water malaria control which the technical staff of TVA has made in the last fifteen years, together with the outstanding national leadership which the staff of the United States Public Health Service has assumed in our country in the general field of malaria control. The manual should long stand as a basic guide to malaria control practices on impounded waters.

The forward-looking policy of management of TVA as regards the desire to hold down the incidence of malaria in a region of potentially high endemicity has resulted not only in a highly effective control program but a closely integrated research and developmental attack on the problems of malaria on impoundages. Numerous publications to date have recounted the advances made, but this manual presents a vast amount of hitherto unpublished data. The latter include a great amount of detail associated with the biology of *Anopheles quadrimaculatus*, the ecology of its breeding environment, particularly the relationship of vegetation to anopheline production, many details of engineering application of control procedures, etc. Normally such details do not appear in scientific papers, but the preparation of a manual afforded an excellent opportunity for their inclusion.

Special attention is directed to the 215 figures which illustrate the manual. Thirty-one of these are kodachrome reproductions of typical breeding areas or of anopheline vectors. These add measurably to the utility of the book. The appendices provide much detail concerning specificity on material or equipment.

It is believed that this manual will be extremely useful to individuals interested in malaria control in general, and while the title indicates a restriction in application to impounded waters, actually the majority of the control procedures may find wide applications under varying conditions. The manner in which the control of mosquito production has been built into the structures and operating schedules of the Tennessee River is a fascinating and exemplary story. The shifting emphasis from costly repetitive measures to those of a permanent nature is apparent. Its success in giving maximum benefits to the people living in the Valley adjacent to the two-thirds of a million acres of water surface of 26 reservoirs has provided a model to be emulated throughout the world.

The current low level of malaria rates in the United States should not permit health workers or administrators to be lulled into a false sense of security as regards the potential dangers of impounded water. Reservoirs will remain as threats to the population adjoining them. The United States Public Health Service and TVA have laid down in this volume the basic principles which should be observed, and it is to be hoped that there will be no relaxing of vigilance in malaria control practices.

Previously the reviewer was closely associated with the staff of TVA and has always enjoyed a cordial relationship with the malaria staff of the United States Public Health Service. He is happy to take this opportunity to congratulate the contributors to this manual not only upon its appearance but their excellent programs which have served as a basis for this publication. The objectives set out in the preface have been accomplished in an admirable manner.

The book is well bound, with clear legible type and excellent reproduction of illustrations. Unfortunately, no index was included, and the reader must depend upon the table of contents to locate the individual topics.

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COLUMBIA UNIVERSITY INITIATES STUDY OF *ANOPHELES ALBIMANUS* IN PUERTO RICO

Project R. G. 1448 for field studies in the bionomics of *Anopheles albimanus* has been approved on the National Institutes of Health Research Grant Program, with funds allocated for fiscal year 1949. The principal investigator, John M. Henderson, Professor of Sanitary Science, Columbia University School of Public Health, has advised that the studies were commenced on September 1, 1948. For the present at least, all of the field studies will be carried on in Puerto Rico. John W. H. Rehn as Chief of Party will carry on the studies in residence, assisted by an entomological aide procured in Puerto Rico.

The studies comprise basic research related to both control and eradication of the species and will be concerned initially with:

- 1) The possible aestivation if immature stages during hot, dry periods.
- 2) Host preferences of the adult under varying conditions of natural competition.
- 3) Nocturnal biting and resting habits in areas where DDT residual house spraying has and has not been performed.
- 4) The possible importation of this and other anopheline species by small inter-island sailing vessels and by non-scheduled cargo and passenger aircraft engaged in international flights and utilizing minor airstrips in Puerto Rico.

The studies will be carried on by Columbia University in cooperation with the School of Tropical Medicine at San Juan, Communicable Disease Center, U. S. P. H. S., District 6, U. S. P. H. S., and the Department of Health of Puerto Rico. Biologist Harold Trapido, Gorgas Memorial Laboratory and Scientist Director Justin M. Andrews and Scientist Harry D. Pratt, C.D.C., U. S. P. H. S., are serving as Consultants. Precipitin examination of field collected specimens will be performed in Atlanta by the Communicable Disease Center.

NATIONAL MALARIA SOCIETY ANNUAL MEETING
NEW ORLEANS—DECEMBER 5-8, 1948

The National Malaria Society will meet conjointly with the American Society of Tropical Medicine, the American Academy of Tropical Medicine, and the American Society of Parasitologists in New Orleans, December 5 to 8, 1948. Registration will begin the afternoon of Sunday, December 5, at the Hotel Roosevelt, the headquarters.

The Department of Tropical Medicine and Public Health, the School of Medicine Tulane University, and the Louisiana State University School of Medicine will act as the hosts in New Orleans.

The National Malaria Society has scheduled four scientific sessions which include a panel discussion on malaria and a joint meeting with the American Society of Parasitologists and the American Society of Tropical Medicine. Panel discussions will also be held by the American Society of Parsitologists on arthropod vectors and the American Society of Tropical Medicine on helminths and protozoa.

On Thursday, December 9, members will be invited to visit the National Leprosarium at Carville and spend the entire day on the hospital grounds. Transportation will be provided without charge.

The 31st annual meeting promises to be one of the most successful the Society has ever held, and each member is urged to attend. A copy of the printed program will be mailed to the membership in advance of the meeting dates.

Hotel Headquarters. The Roosevelt Hotel will be the headquarters and can accommodate most of the members. Rooms will be available at the following hotels at the rates indicated:

<i>Hotel</i>	<i>Single Room</i>	<i>Double Room</i>
Roosevelt.....	\$5.00, 6.00, 7.00	\$9.00, 10.00, 12.00
Jung.....	5.00, 6.00, 7.00	8.00, 9.00
Monteleone.....	5.00, 6.00, 7.00	8.00, 9.00, 10.00
St. Charles.....	5.00, 6.00, 7.00	9.00, 10.00, 12.00
New Orleans.....	4.50	6.00, 7.00
DeSoto.....	5.00	7.00
Lafayette.....	4.00	6.00, 7.00
Pontchartrain.....	————	8.00, 10.00, 12.00

While all of these hotels are centrally located, the DeSota, Lafayette, and the Pontchartrain are a considerable distance from the headquarters. It should also be noted that there is a 5-day limit on the occupancy of all hotel rooms. To request reservations, please contact Mr. Sam Fowlkes, Chairman, Housing Bureau, 315 Camp Street, New Orleans 12. Applications for hotel rooms should be submitted as early as possible and at least by November 1, 1948.



